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Ikeda et al.

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(54) **PLASMA DISPLAY DEVICE**

(75) Inventors: **Motofumi Ikeda**, Chuo (JP);
Yoshichika Sato, Chuo (JP); **Nobuhiko Saegusa**, Chuo (JP); **Shigeru Iwaoka**, Chuo (JP)

(73) Assignee: **Panasonic Corporation**, Osaka (JP)

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

G09G 3/28 (2006.01)

(52) **U.S. Cl.** **345/71; 345/60**

(58) **Field of Classification Search** **345/55, 345/60, 63, 64, 71, 72, 204, 205, 206; 315/167, 315/169.1, 169.4**

See application file for complete search history.

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Primary Examiner—My-Chau T Tran

(74) Attorney, Agent, or Firm—Drinker Biddle & Reath LLP

(57) **ABSTRACT**

A plasma display device which selectively generates address discharge in each display cell in accordance with pixel data based on a video signal in an address period, applies a sustain pulse between row electrodes forming each row electrode pair in a sustain period, and applies, in the sustain period, a discharge timing control pulse to one row electrode of each row electrode pair, so that the discharge timing control pulse partly overlaps with a first sustain pulse in terms of time, which is applied to the other row electrode of each row electrode pair.

5 Claims, 13 Drawing Sheets

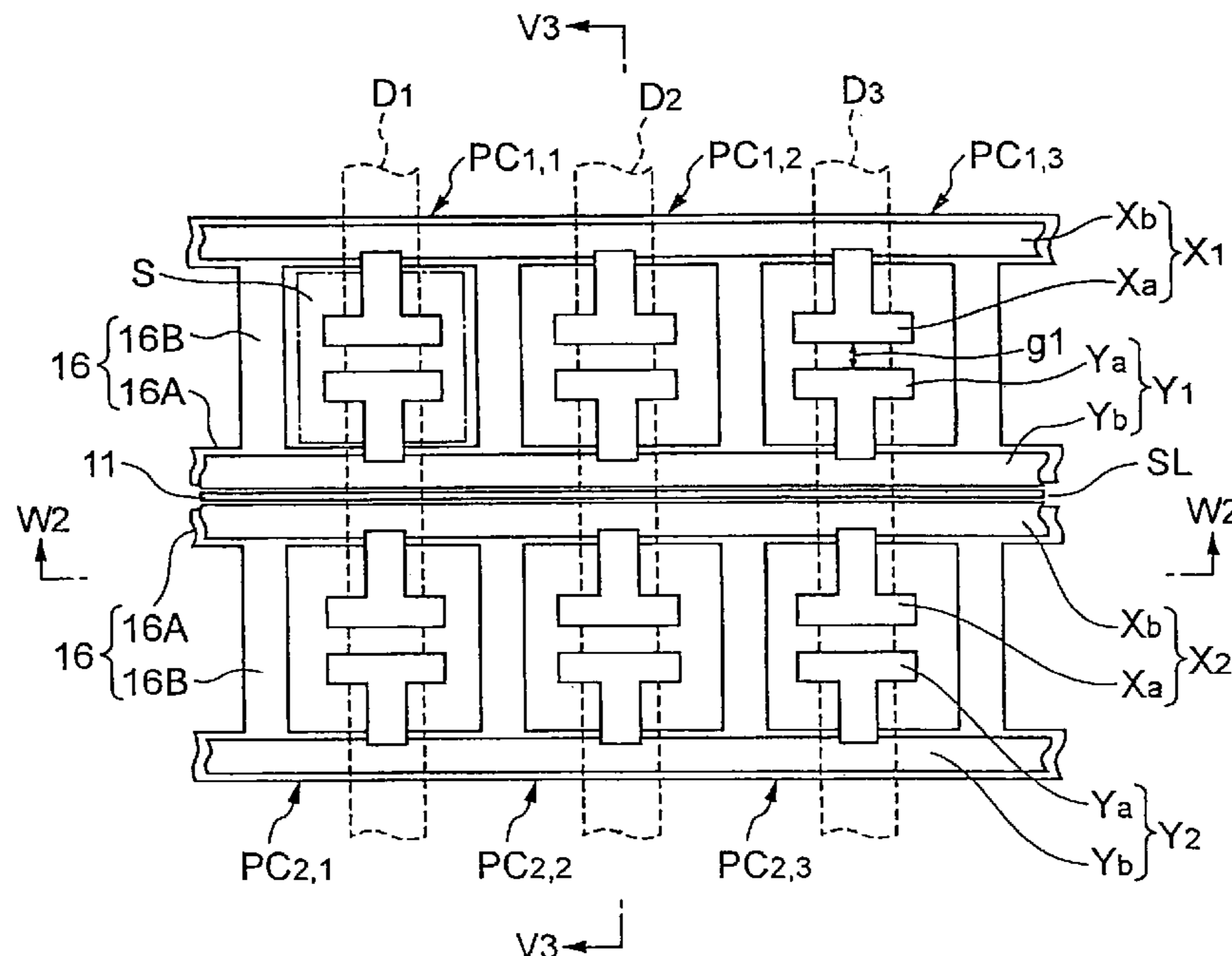


FIG. 1

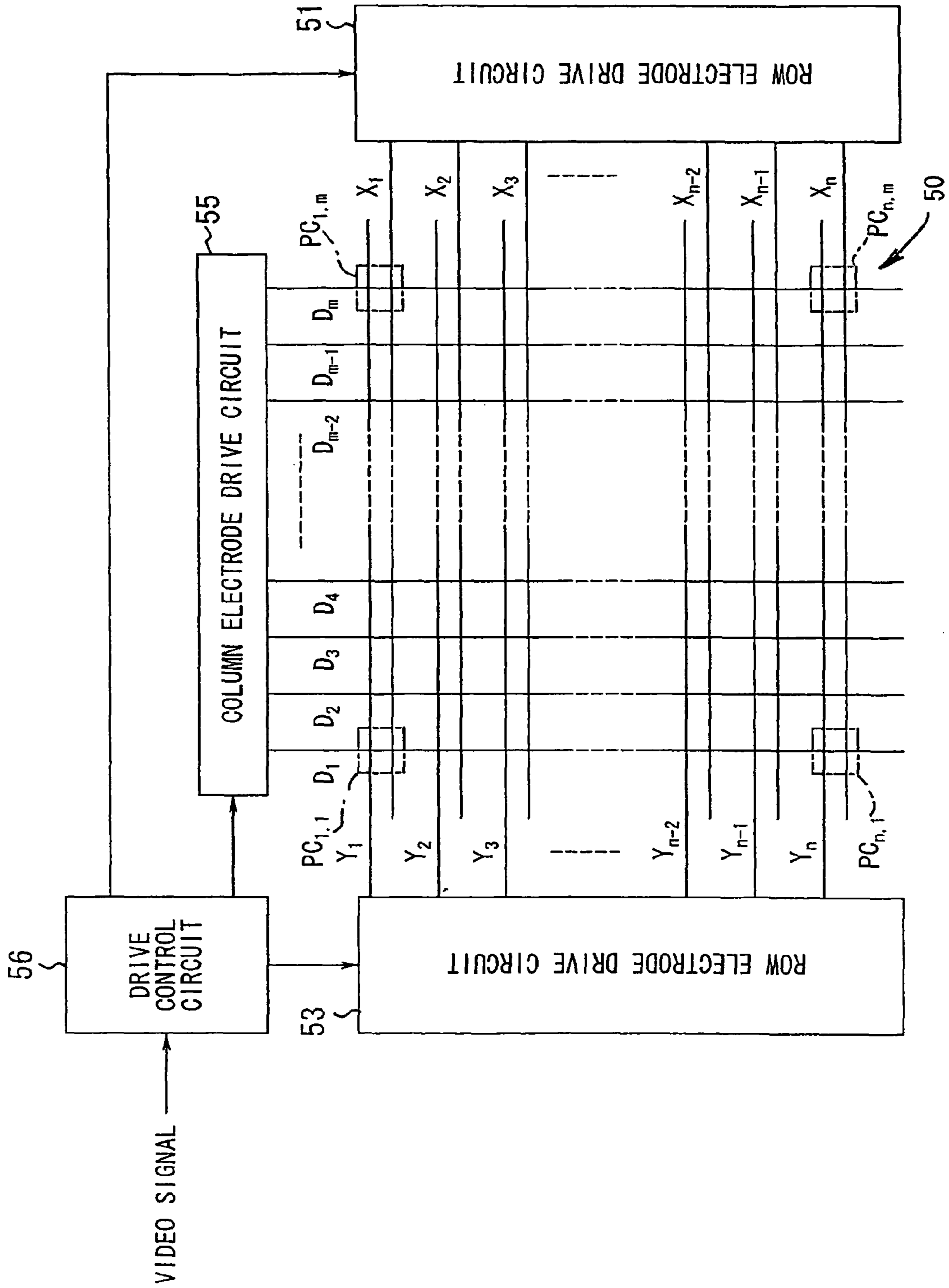


FIG. 2

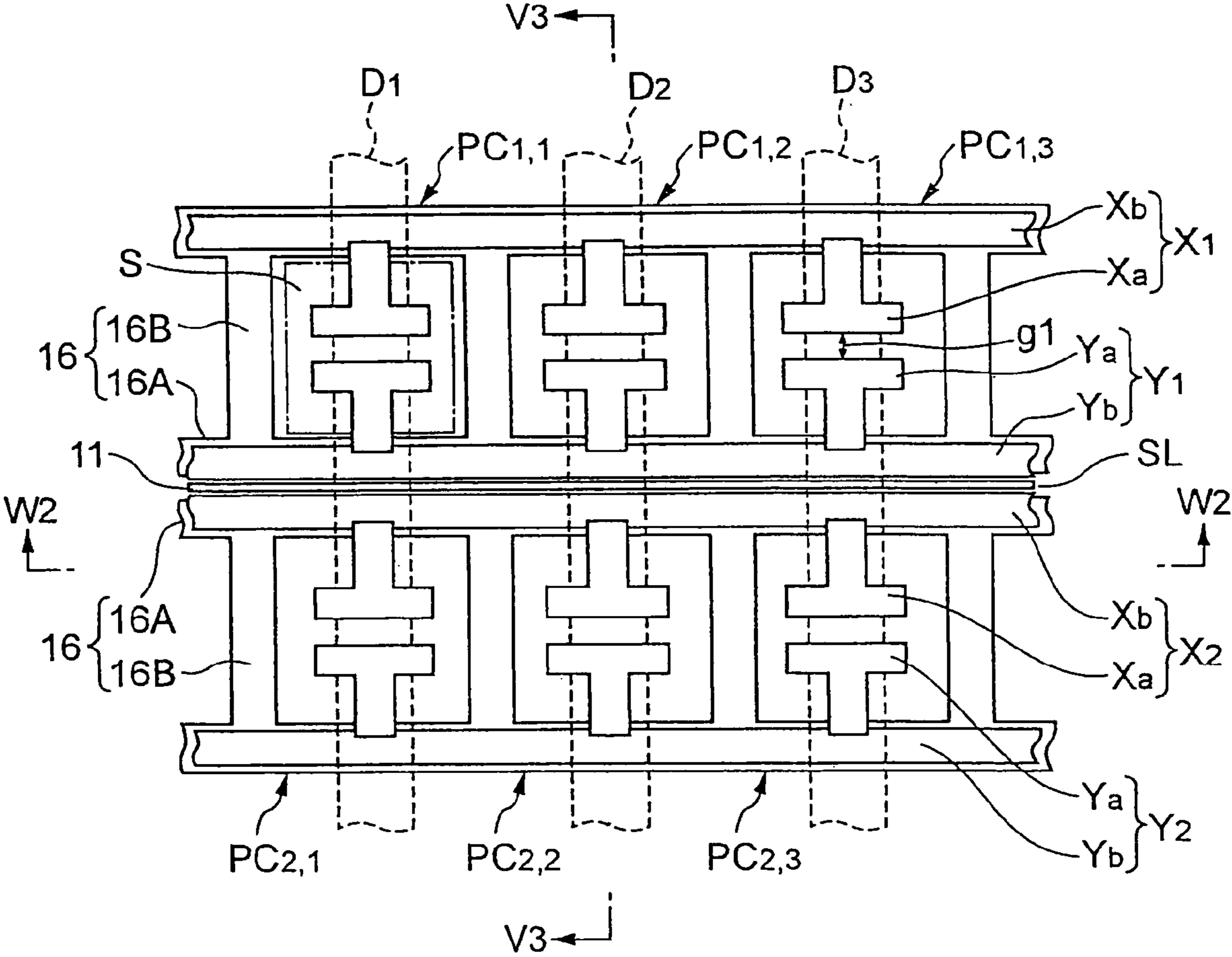


FIG. 3

CROSS - SECTION ALONG V3 - V3

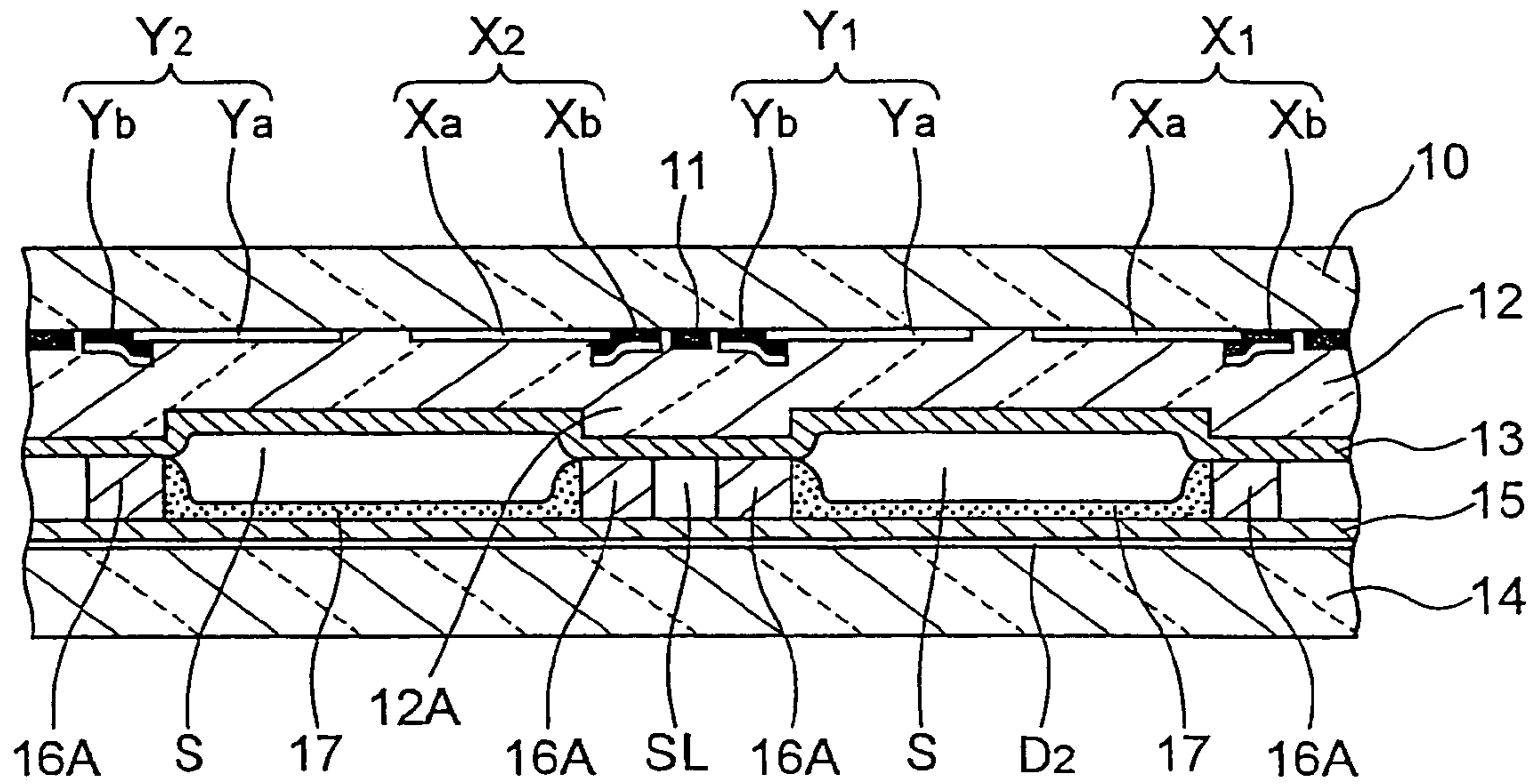


FIG. 4

CROSS - SECTION ALONG W2 - W2

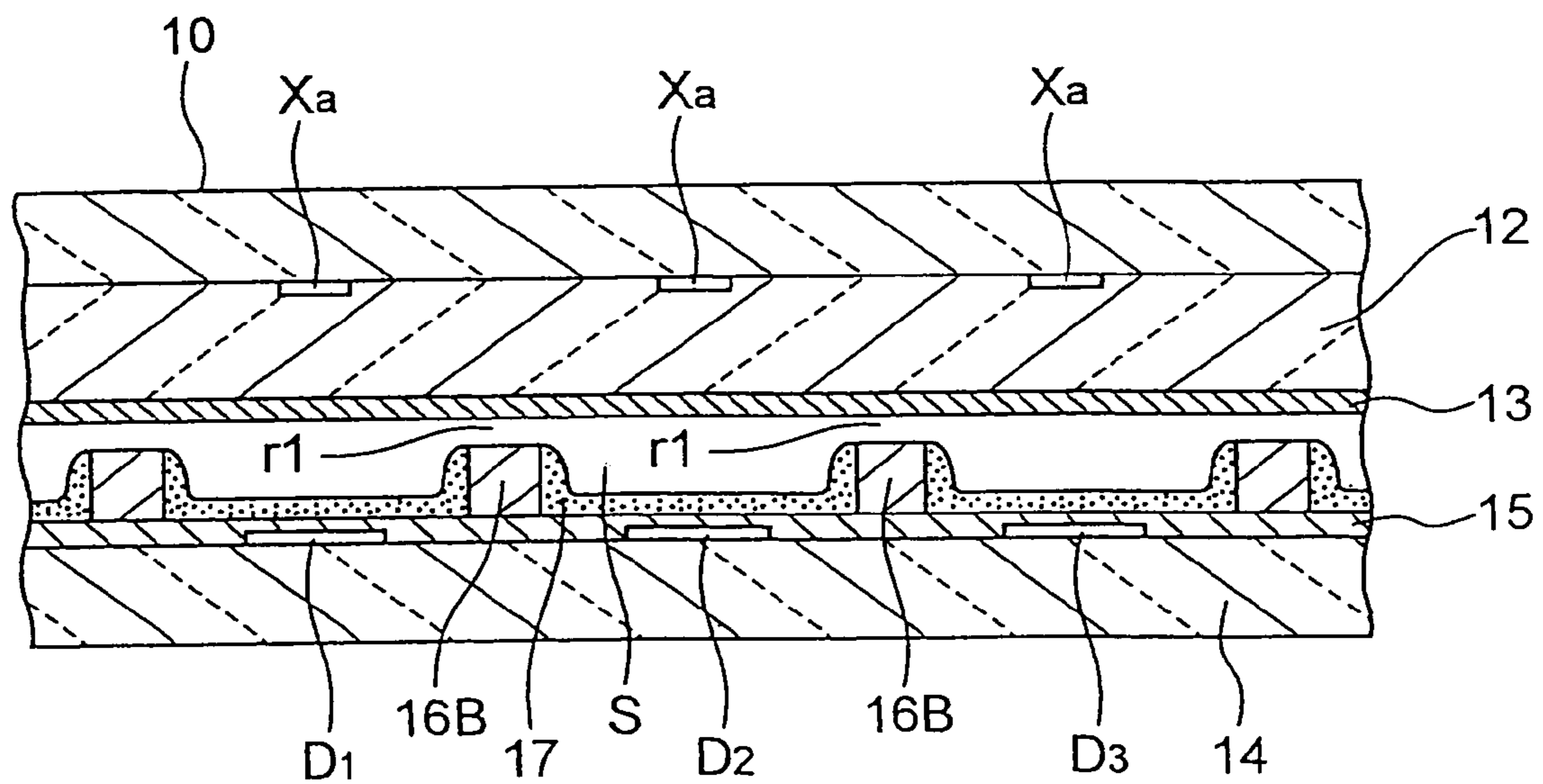


FIG. 5

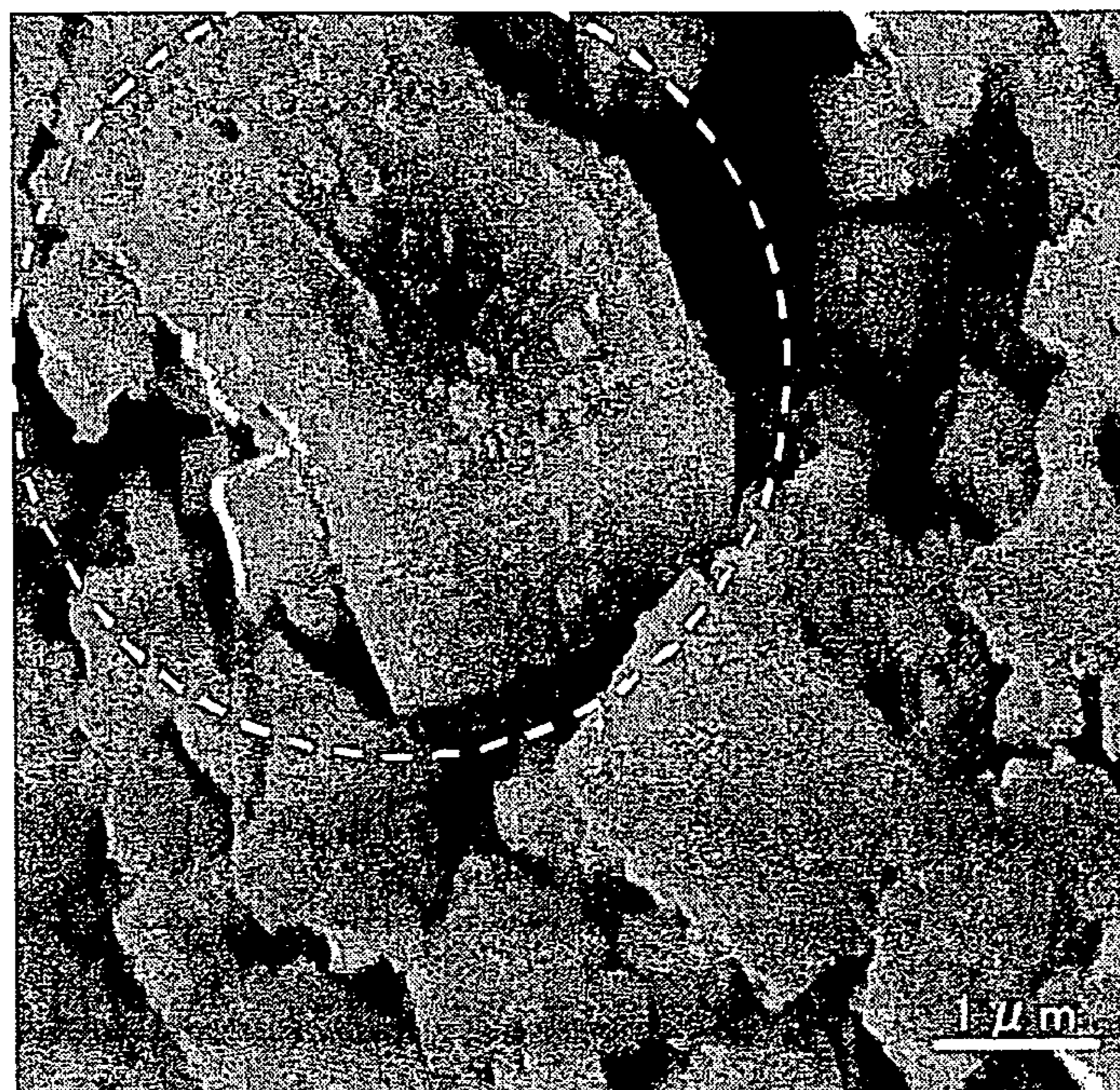


FIG. 6

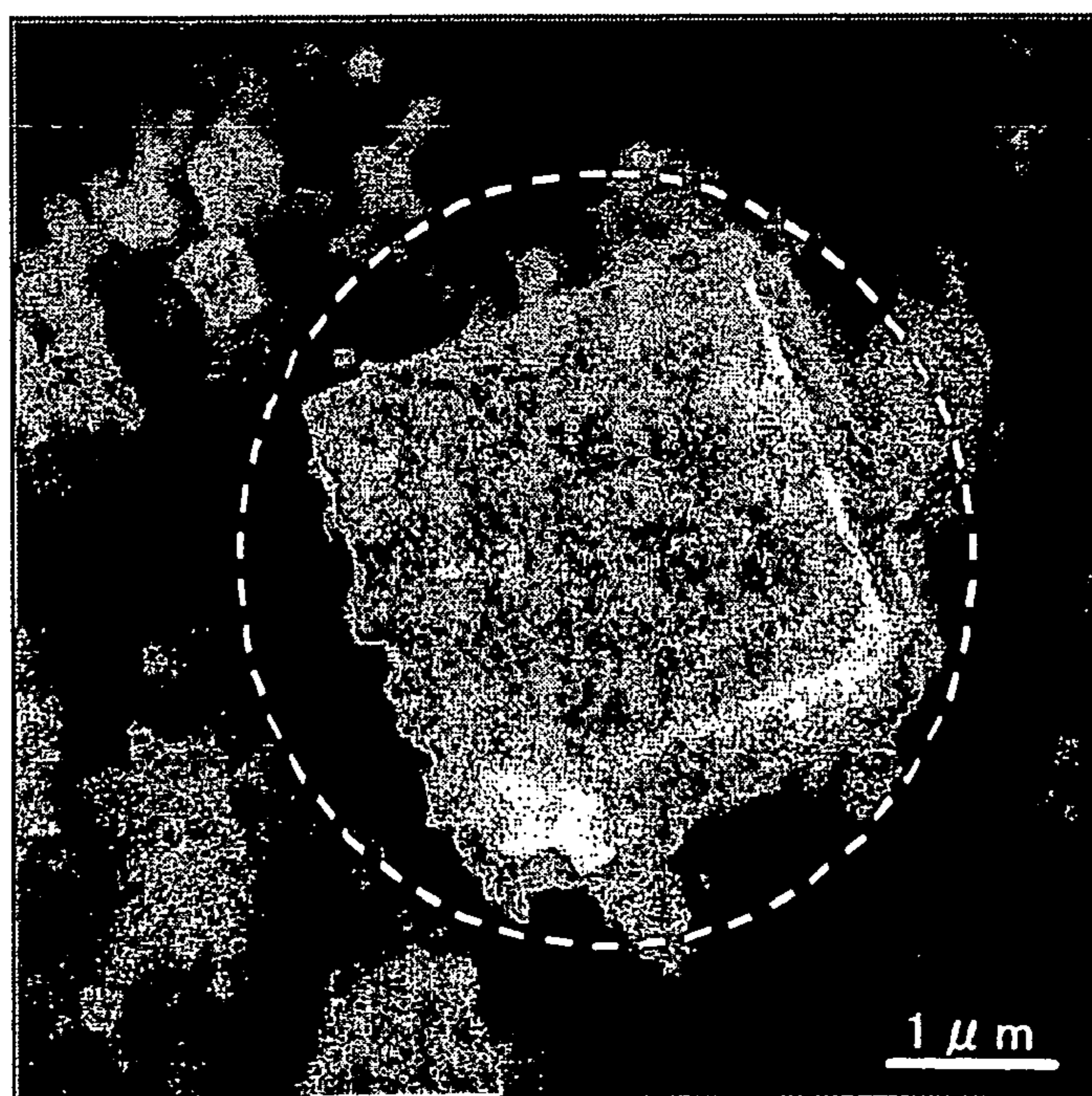


FIG. 7

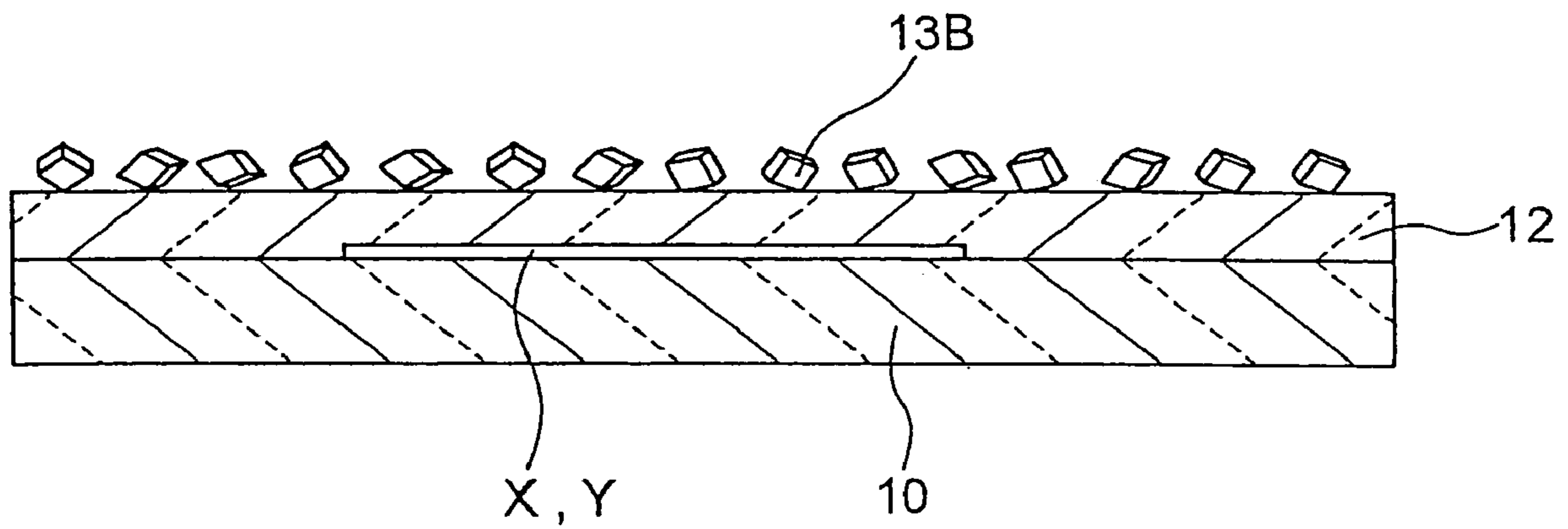


FIG. 8

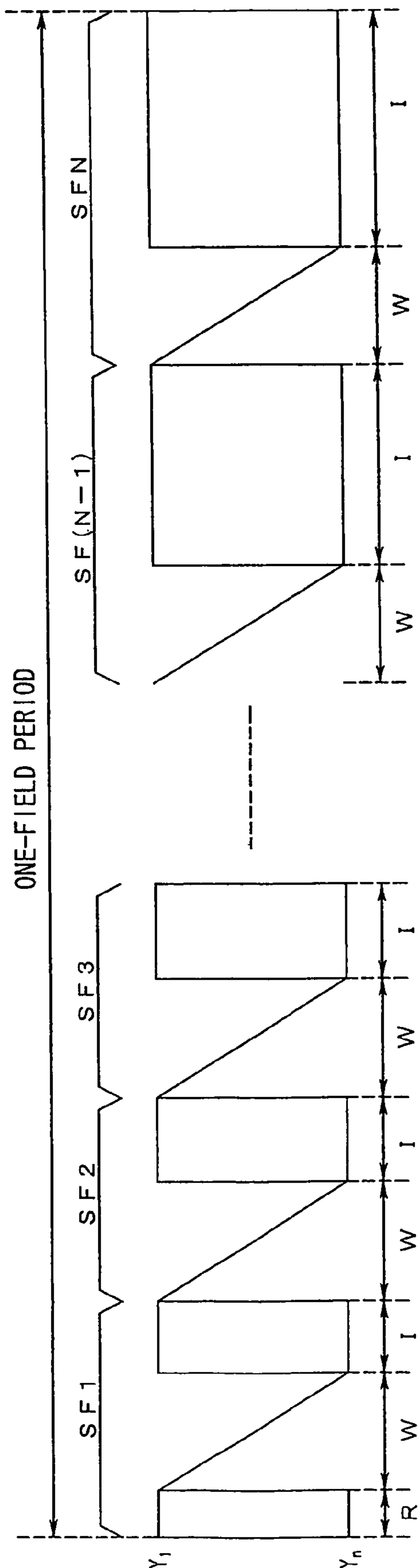


FIG. 9

| LIGHT EMISSION PATTERN | | | | | | | | | | | | |
|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|
| GRAY SCALE | S F 1 | S F 2 | S F 3 | S F 4 | S F 5 | S F 6 | S F 7 | S F 8 | S F 9 | S F 10 | S F 11 | S F 12 |
| 1ST | ● | | | | | | | | | | | |
| 2ND | ○ | ● | | | | | | | | | | |
| 3RD | ○ | ○ | ● | | | | | | | | | |
| 4TH | ○ | ○ | ○ | ● | | | | | | | | |
| 5TH | ○ | ○ | ○ | ○ | ● | | | | | | | |
| 6TH | ○ | ○ | ○ | ○ | ○ | ● | | | | | | |
| 7TH | ○ | ○ | ○ | ○ | ○ | ○ | ● | | | | | |
| 8TH | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | | | | |
| 9TH | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | | | |
| 10TH | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | | |
| 11TH | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | |
| 12TH | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● |
| 13YH | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

○ : SF EMITTING LIGHT

● : SF STOPPING LIGHT EMISSION BY SELECTIVE ERASURE ADDRESS DISCHARGE

FIG. 10

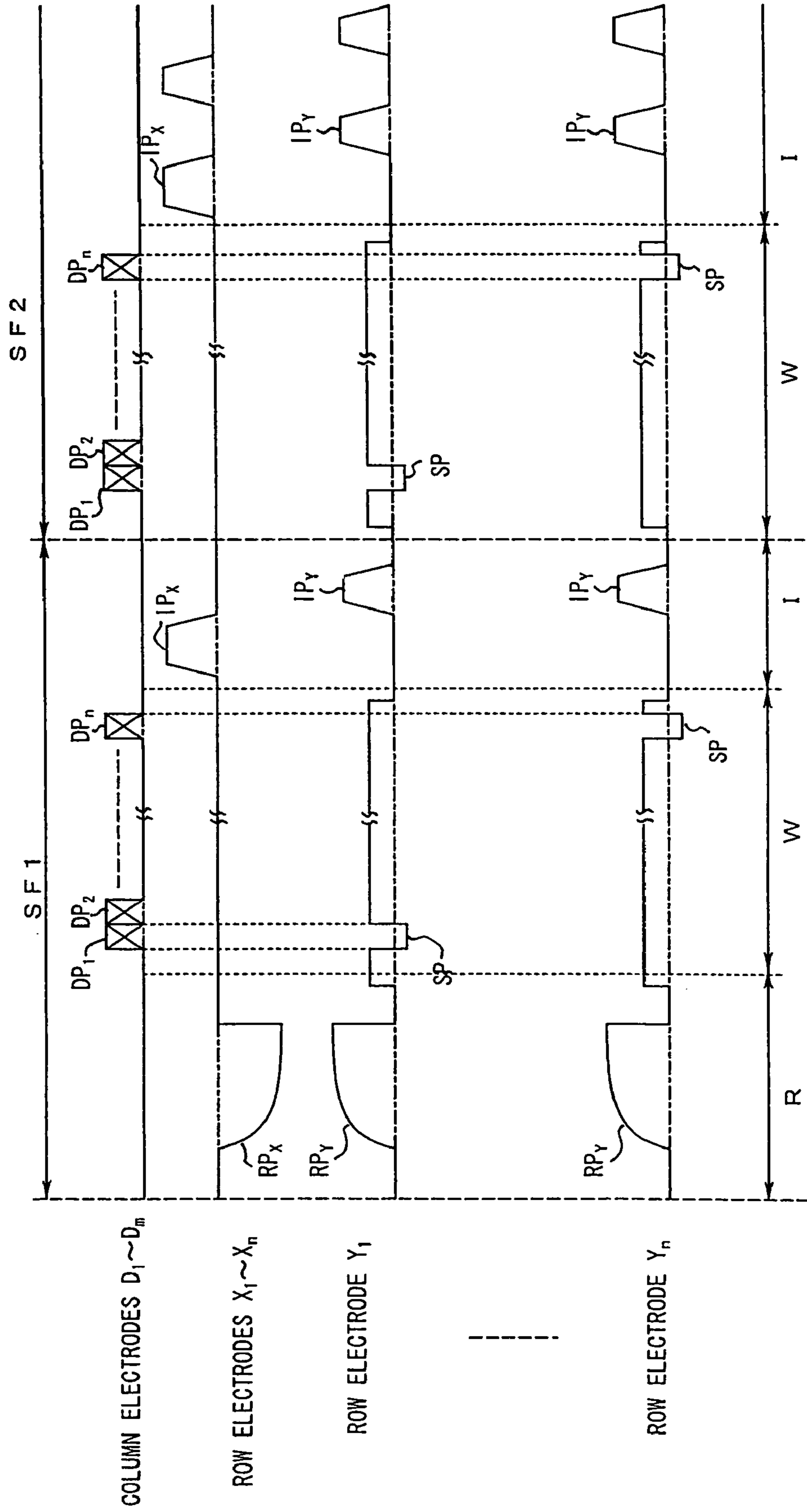


FIG. 11

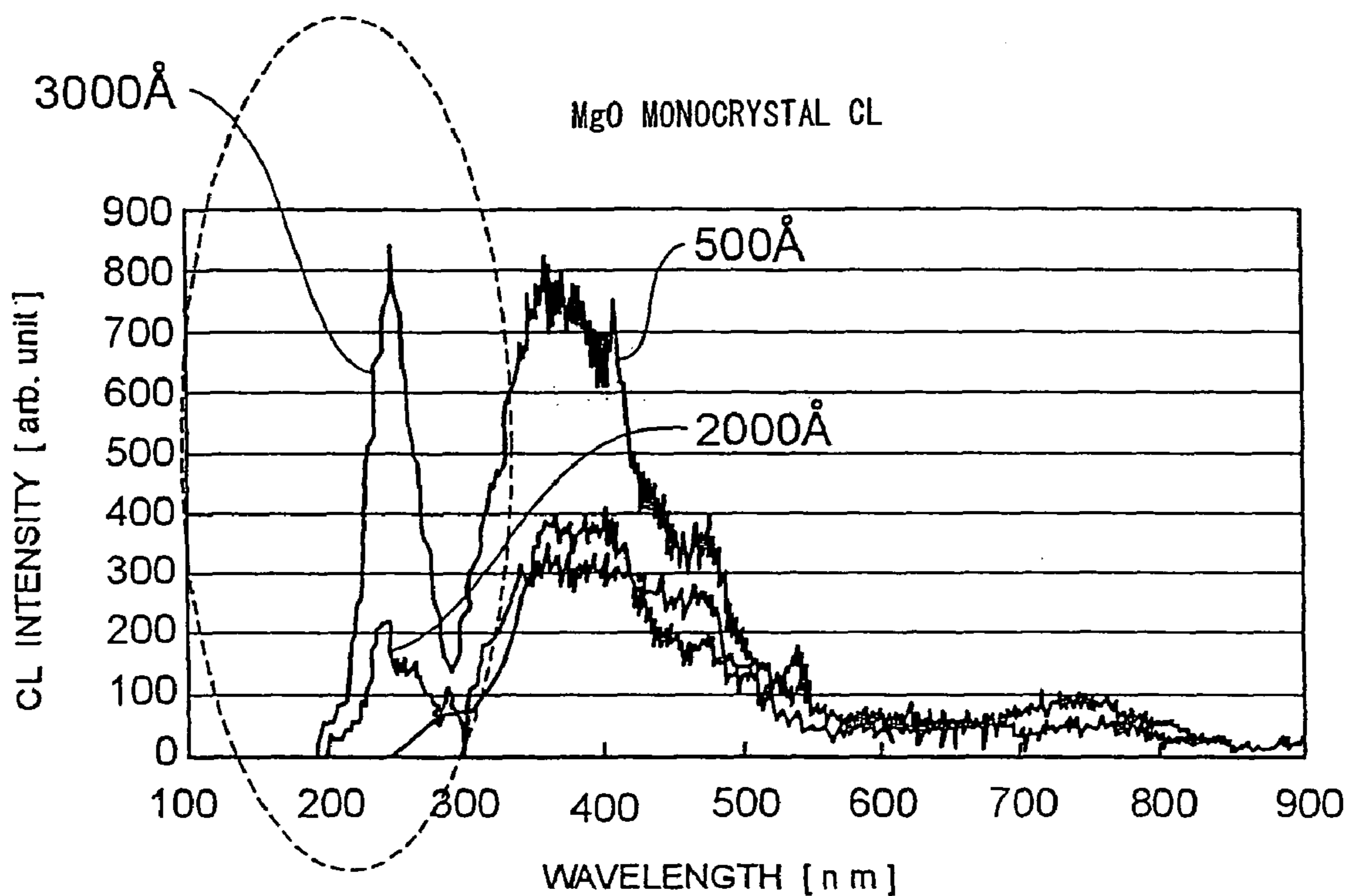


FIG. 12

PEAK INTENSITY OF MgO MONOCRYSTAL AT 235 nm versus GRAIN DIAMETER

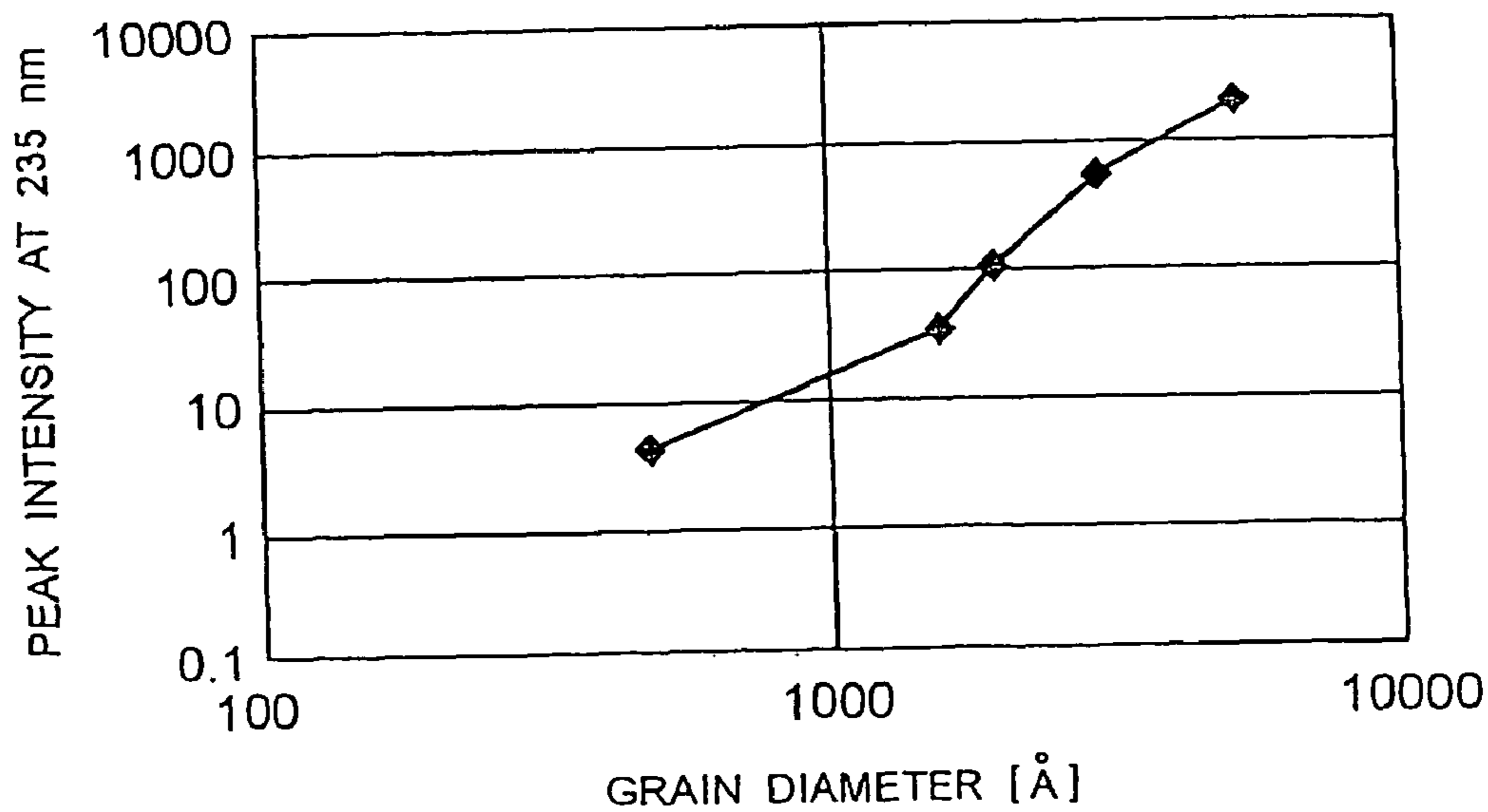


FIG. 13

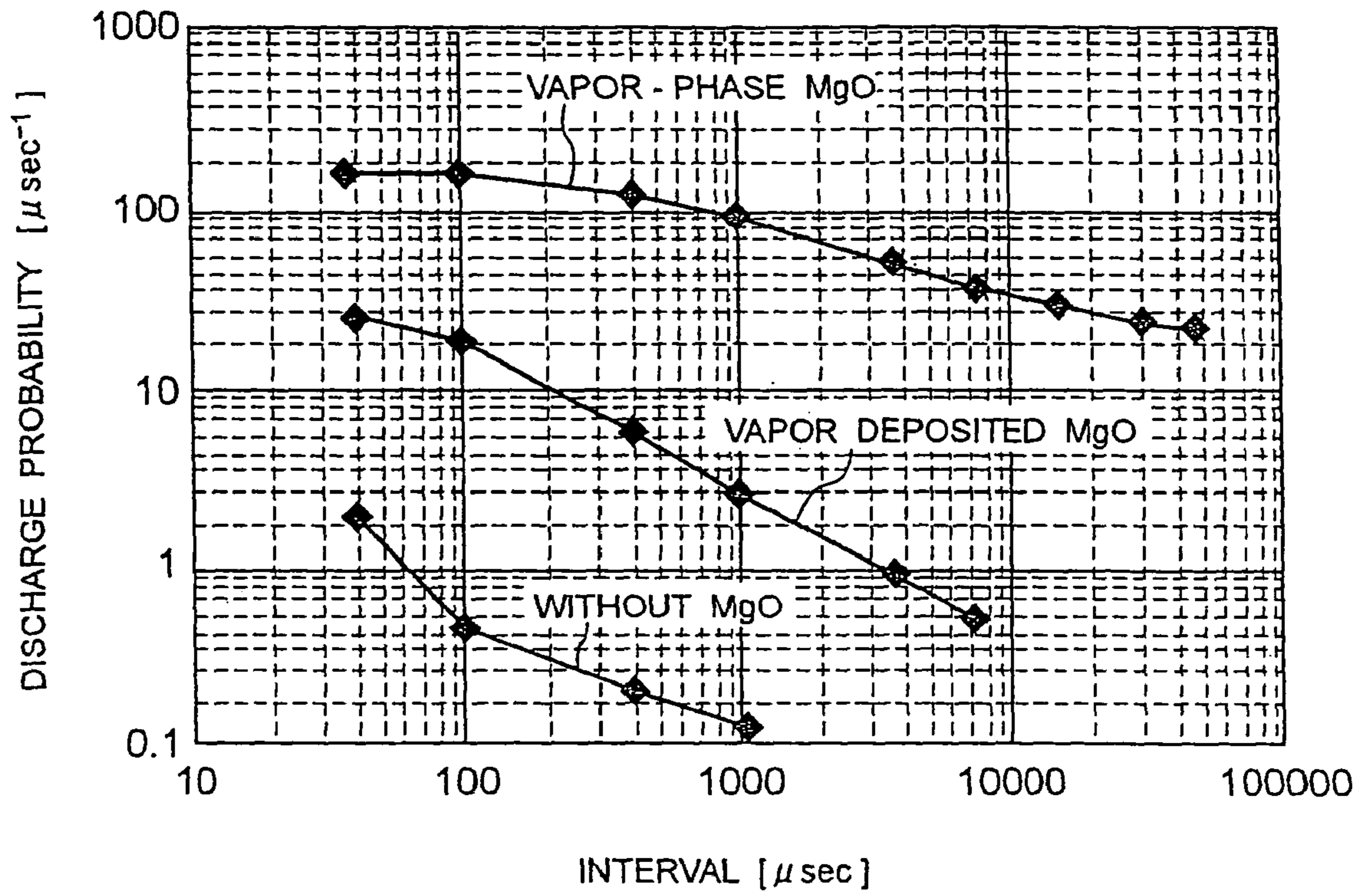


FIG. 14

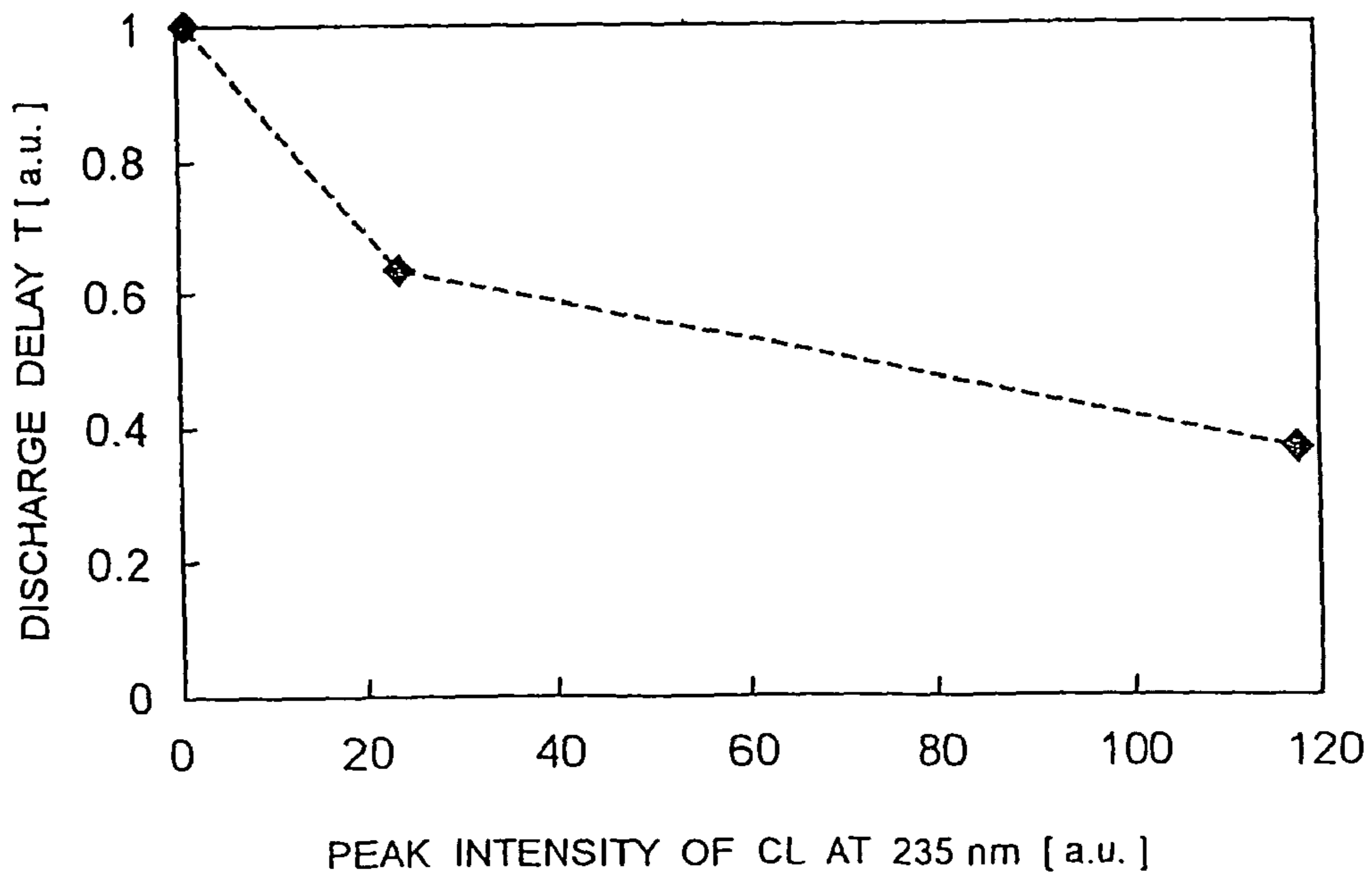


FIG. 15

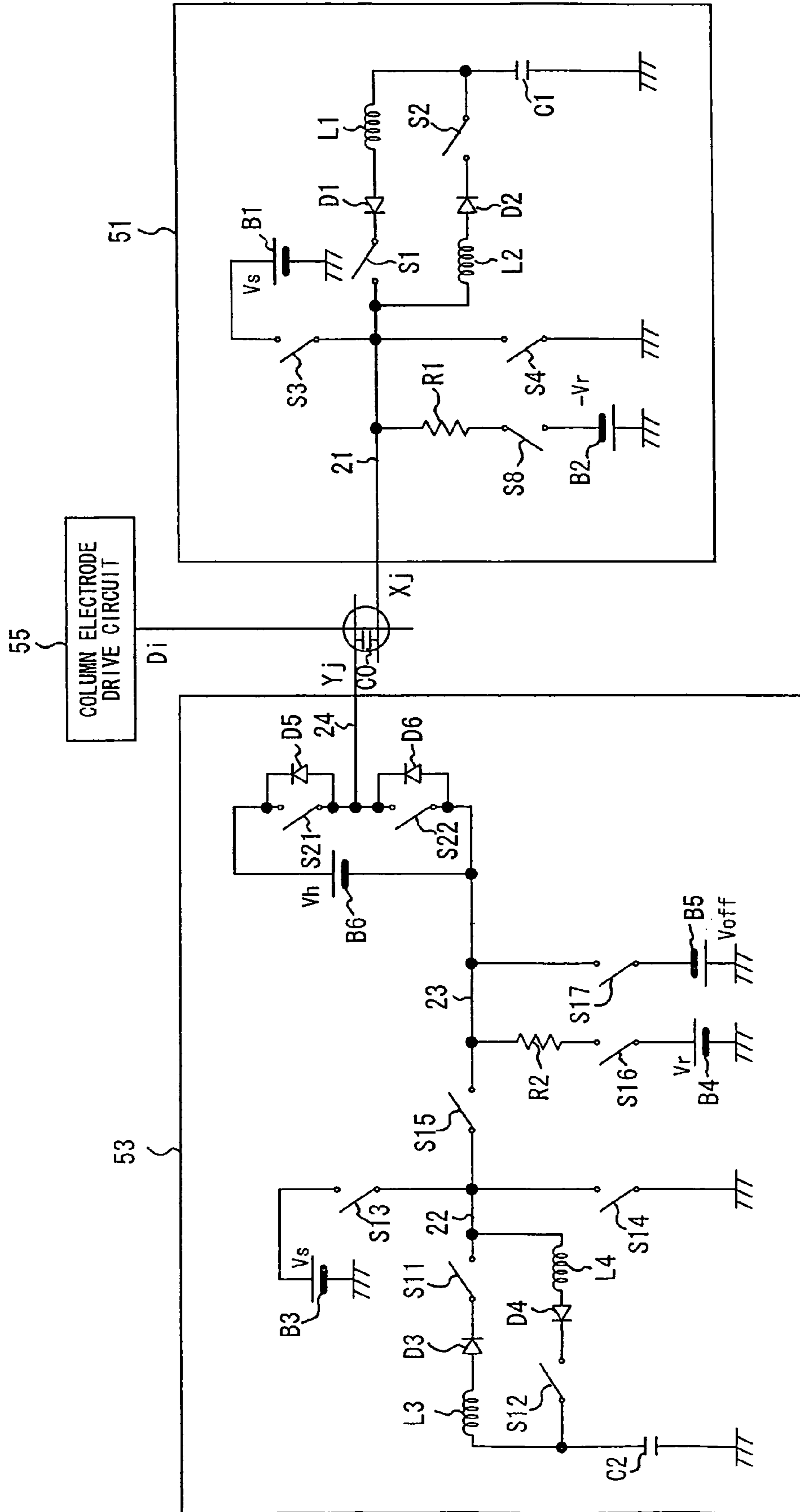


FIG. 16

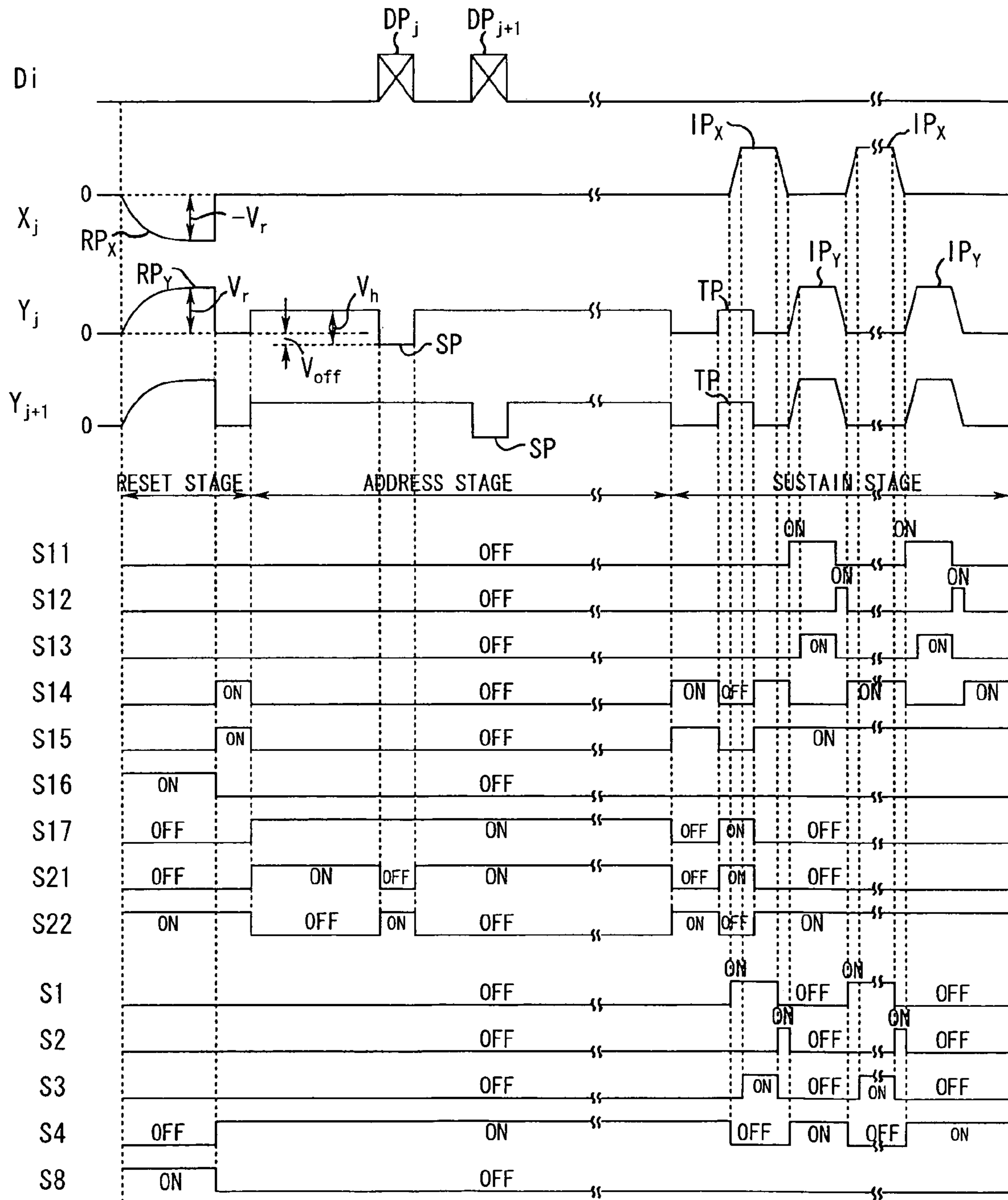


FIG. 18

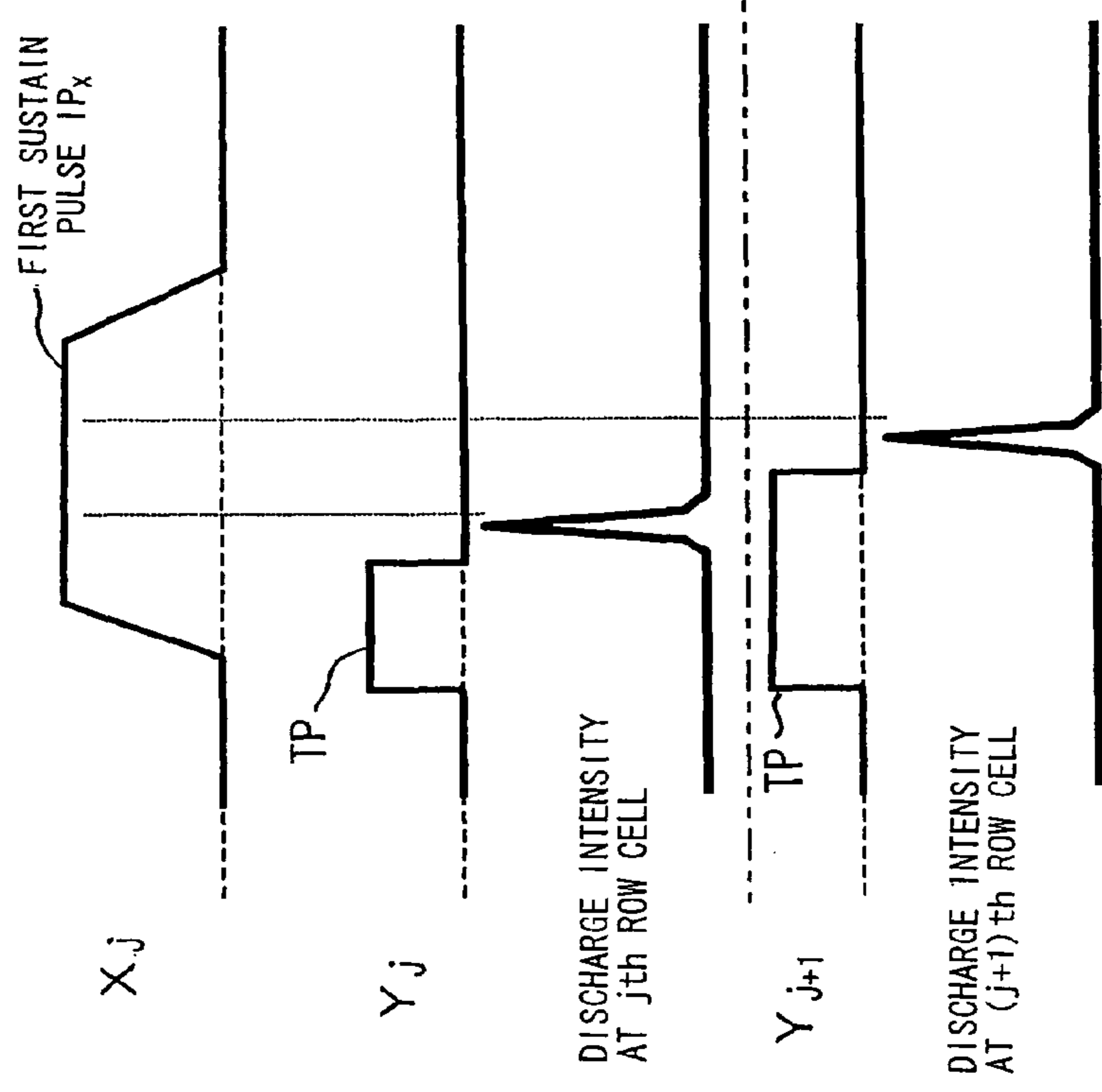
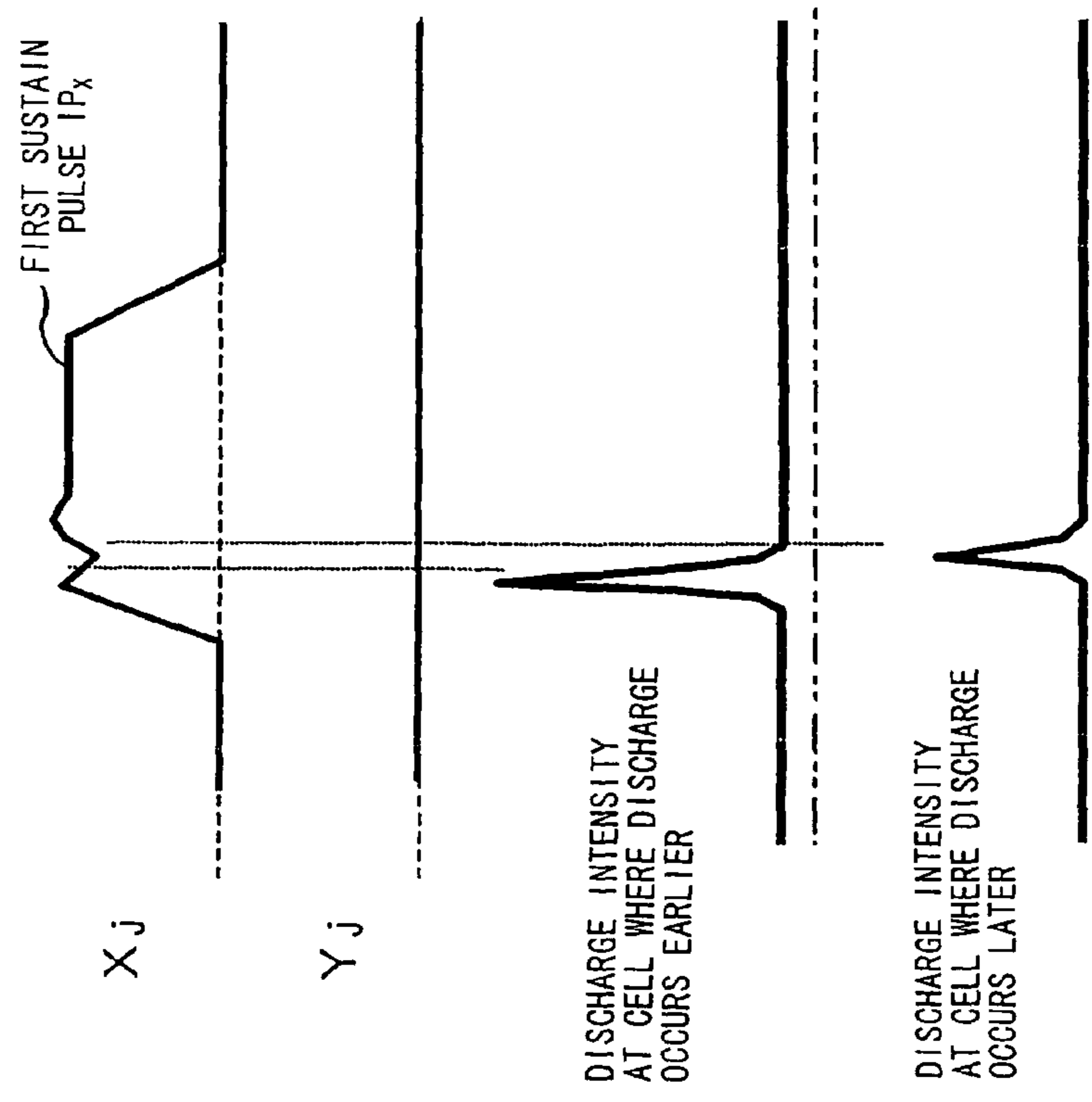


FIG. 17



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PLASMA DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a plasma display device using a plasma display panel.

2. Description of the Related Background Art

Currently, as a thin display device, an AC type (alternating discharge type) plasma display panel becomes commercially available. In the plasma display panel, two substrates, that is, a front glass substrate and a rear glass substrate are disposed with a predetermined space as faced to each other. On the inner surface (the surface facing the rear glass substrate) of the front glass substrate as a display surface, multiple row electrode pairs are formed as sustain electrode pairs, which are paired with each other and extended in parallel. On the rear glass substrate, multiple column electrodes are extended and formed as address electrodes as intersecting with the row electrode pairs, and are coated with a fluorescent material. When seen from the display surface side, a display cell corresponding to a pixel is formed at the intersection part of the row electrode pair with the column electrode. To the plasma display panel, gray scale addressing using a subfield method is implemented in order to obtain halftone display brightness as corresponding to input video signals.

In gray scale addressing based on the subfield method, a plurality of subfields are provided. In each of the subfields to which the number of times (or periods) to do light emission is assigned, display addressing is implemented to one field of video signals. Further, in each of the subfields, an address stage and a sustain stage are in turn implemented. In the address stage, in accordance with input video signals, selective discharge is selectively generated between the row electrode and the column electrode in each of the display cells to form a predetermined amount of wall electric charge (or remove it). In the sustain stage, only a display cell where a predetermined amount of wall electric charge is formed is repeatedly discharged, and a light emission state in association with that discharge is maintained. Furthermore, at least at the starting subfield, prior to the address stage, an initializing stage is implemented. In the initializing stage, in-all the display cells, reset discharge is generated between the paired row electrodes to implement the initializing stage which initializes the amount of wall electric charge remaining in all the display cells.

In the sustain stage, in the case where many display cells are set in the lighting state and a sustain pulse is applied to generate discharge in many cells almost at the same time, a large amount of current is carried momentarily, and distortion occurs in the voltage waveform of the sustain pulse. Consequently, in accordance with a slight shift in a time point to start discharge, the voltage value being applied in discharge is varied in each of the display cells, variation occurs in discharge intensity, and thus display quality might be deteriorated.

SUMMARY OF THE INVENTION

It is an object of the present invention is to provide a plasma display device which can prevent variation in discharge intensity in each display cell to improve display quality.

A plasma display device according to the invention is a device for displaying an image on a plasma display panel in accordance with an input video signal, the plasma display panel having a plurality of row electrode pairs, and a plurality of column electrodes intersecting with the plurality of row

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electrode pairs, so as to form display cells at the intersections, respectively, and a display period for one field of the input video signal being configured of a plurality of subfields each formed of an address period and a sustain period for the image display, the plasma display device comprising: an addressing portion which selectively generates address discharge in each of the display cells in accordance with pixel data based on the video signal in the address period; a sustaining portion which applies a sustain pulse between row electrodes forming each of the row electrode pairs in the sustain period; and a discharge timing controller which applies, in the sustain period, a discharge timing control pulse of a same polarity as that of the sustain pulse, to one row electrodes of the row electrode pairs, so that the discharge timing control pulse partly overlaps with a first sustain pulse in terms of time, which is applied to the other row electrodes of the row electrode pairs by the sustaining portion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating an outline configuration of a plasma display device according to the invention;

FIG. 2 is a front view schematically illustrating the internal configuration of PDP seen from the display surface side of the device shown in FIG. 1;

FIG. 3 is a diagram illustrating a cross section on line V3-V3 shown in FIG. 2;

FIG. 4 is a diagram illustrating a cross section on line W2-W2 shown in FIG. 2;

FIG. 5 is a diagram illustrating magnesium oxide monocrystals having a cubic polycrystal structure;

FIG. 6 is a diagram illustrating a magnesium oxide monocrystal having a cubic polycrystal structure;

FIG. 7 is a diagram illustrating a form when magnesium oxide monocrystal powder is attached to the surface of a dielectric layer and an increased dielectric layer to form a magnesium oxide layer;

FIG. 8 is a diagram illustrating an exemplary light emission addressing sequence adopted in the plasma display device;

FIG. 9 is a diagram illustrating light emission patterns of the plasma display device;

FIG. 10 is a diagram illustrating various drive pulses to be applied to PDP and application timing thereof in accordance with the light emission addressing sequence shown in FIG. 8;

FIG. 11 is a graph illustrating the relationship between the particle diameter of magnesium oxide monocrystal powder and the wavelength of CL light emission;

FIG. 12 is a graph illustrating the relationship between the particle diameter of magnesium oxide monocrystal powder and the intensity of CL light emission at 235 nm;

FIG. 13 is a diagram illustrating a discharge probability when no magnesium oxide layer is constructed in a display cell, a discharge probability when a magnesium oxide layer is constructed by traditional vapor deposition, and a discharge probability when a magnesium oxide layer of a polycrystal structure is constructed;

FIG. 14 is a diagram illustrating the correspondence between CL light emission intensity at a 235-nm peak and discharge delay time;

FIG. 15 is a circuit diagram illustrating a specific configuration of an X-row electrode drive circuit and a Y-row electrode drive circuit in the device shown in FIG. 1;

FIG. 16 is a diagram illustrating switching operations and voltage waveforms of each electrode in the drive circuit shown in FIG. 15;

FIG. 17 is a view showing discharge intensities that are provided at a cell where a discharge occurs earlier and at a cell

where a discharge occurs later, when a first sustain pulse is applied thereto in a sustain stage; and

FIG. 18 is a view showing discharge intensities that are provided at respective display cell on electrodes Y_j , and Y_{j+1} at the time of application of a first sustain pulse when a discharge timing control pulse is applied thereto in a sustain stage.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, an embodiment according to the present invention will be described in detail with reference to the drawings.

FIG. 1 is a diagram illustrating an outline configuration of a plasma display device according to the invention.

As shown in FIG. 1, the plasma display device is configured of a PDP 50 as a plasma display panel, an X-row electrode drive circuit 51, a Y-row electrode drive circuit 53, a column electrode drive circuit 55, and a drive control circuit 56.

In the PDP 50, column electrodes D_1 to D_m are extended and arranged in the longitudinal direction (vertical direction) of a two-dimensional display screen, and row electrodes X_1 to X_n and row electrodes Y_1 to Y_n are extended and arranged in the lateral direction (the horizontal direction) thereof. The row electrodes X_1 to X_n and row electrodes Y_1 to Y_n form row electrode pairs (Y_1, X_1) , (Y_2, X_2) , (Y_3, X_3) , . . . , (Y_n, X_n) which are paired with those adjacent to each other and which serve as the first display line to the nth display line in the PDP 50. In each intersection part of the display lines with the column electrodes D_1 to D_m (areas surrounded by dashed lines in FIG. 1), a display cell PC which serves as a pixel is formed. More specifically, in the PDP 50, the display cells $PC_{1,1}$ to $PC_{1,m}$ belonging to the first display line, the display cells $PC_{2,1}$ to $PC_{2,m}$ belonging to the second display line, and the display cells $PC_{n,1}$ to $PC_{n,m}$ belonging to the nth display line are each arranged in a matrix.

Each of the column electrodes D_1 to D_m of the PDP 50 is connected to the column electrode drive circuit 55, each of the row electrodes X_1 to X_n is connected to the X-row electrode drive circuit 51, and each of the row electrodes Y_1 to Y_n is connected to the Y-row electrode drive circuit 53.

FIG. 2 is a front view schematically illustrating the internal configuration of the PDP 50 seen from the display surface side. FIG. 2 depicts each of the intersection parts of each of the column electrodes D_1 to D_3 with the first display line (Y_1, X_1) and the second display line (Y_2, X_2) in the PDP 50. FIG. 3 depicts a diagram illustrating a cross section of the PDP 50 at a line V3-V3 in FIG. 2, and FIG. 4 depicts a diagram illustrating a cross section of the PDP 50 at a line W2-W2 in FIG. 2.

As shown in FIG. 2, each of the row electrodes X is configured of a bus electrode Xb (main portion) extended in the horizontal direction in the two-dimensional display screen and a T-shaped transparent electrode Xa (projected portion) formed as contacted with the position corresponding to each of the display cells PC on the bus electrode Xb. Each of the row electrodes Y is configured of a bus electrode Yb extended in the horizontal direction of the two-dimensional display screen and a T-shaped transparent electrode Ya formed as contacted with the position corresponding to each of the display cells PC on the bus electrode Yb. The transparent electrodes Xa and Ya oppose each other via a discharge gap g1 which has a predetermined length. The transparent electrodes Xa and Ya are formed of a transparent conductive film such as ITO, and the bus electrodes Xb and Yb are formed of a metal film, for example. As shown in FIG. 3, for the row electrode

X formed of the transparent electrode Xa and the bus electrode Xb, and for the row electrode Y formed of the transparent electrode Ya and the bus electrode Yb, the front sides thereof are formed on the rear side of a front transparent substrate 10 to be the display surface of the PDP 50. The transparent electrodes Xa and Ya in each row electrode pair (X, Y) are extended to the counterpart row electrode side to be paired, and each have a wide portion near the discharge gap g1, and a narrow portion connecting between the wide portion and the bus electrode. The flat tops of the wide portions of the transparent electrodes Xa and Ya are faced to each other through the discharge gap g1. Moreover, on the rear side of the front transparent substrate 10, a black or dark light absorbing layer (shade layer) 11 extended in the horizontal direction of the two-dimensional display screen is formed between a pair of the row electrode pair (X_1, Y_1) and the row electrode pair (X_2, Y_2) adjacent to this row electrode pair. Furthermore, on the rear side of the front transparent substrate 10, a dielectric layer 12 is formed so as to cover the row electrode pair (X, Y). On the rear side of the dielectric layer 12 (the surface opposite to the surface to which the row electrode pair is contacted), an increased dielectric layer 12A is formed at the portion corresponding to the area where a light absorbing layer 11 and the bus electrodes Xb and Yb adjacent to the light absorbing layer 11 are formed as shown in FIG. 3. On the surface of the dielectric layer 12 and the increased dielectric layer 12A, a magnesium oxide layer 13 including vapor phase magnesium oxide (MgO) monocrystal powder, described later, is formed.

On the other hand, on a rear substrate 14 disposed in parallel with the front transparent substrate 10, each of the column electrodes D is formed as extended in the direction orthogonal to the row electrode pair (X, Y) at the position facing the transparent electrodes Xa and Ya in each row electrode pair (X, Y). On the rear substrate 14, a white column electrode protective layer 15 which covers the column electrode D is further formed. On the column electrode protective layer 15, partition 16 is formed. The partition 16 is formed in a ladder shape of a lateral wall 16A extended in the lateral direction of the two-dimensional display screen at the position corresponding to the bus electrodes Xb and Yb of each row electrode pair (X, Y), and of a vertical wall 16B extended in the longitudinal direction of the two-dimensional display screen at the middle between the column electrodes D adjacent to each other. In addition, the partition 16 in a ladder shape as shown in FIG. 2 are formed at every display line of the PDP 50, and a space SL exists between the partitions 16 adjacent to each other as shown in FIG. 2. Besides, the partitions 16 in a ladder shape partition the display cells PC including a discharge space S, and the transparent electrodes Xa and Ya, each of them is separated. In the discharge space S, discharge gas including xenon gas is filled. On the side surface of the lateral wall 16A, the side surface of the vertical wall 16B, and the surface of the column electrode protective layer 15 in each of the display cells PC, a fluorescent material layer 17 is formed so as to cover the entire surfaces thereof as shown in FIG. 3. The fluorescent material layer 17 is actually formed of three types of fluorescent materials: a fluorescent material for red light emission, a fluorescent material for green light emission, and a fluorescent material for blue light emission. The discharge space S and the space SL in each of the display cells PC are closed to each other by abutting the magnesium oxide layer 13 against the lateral wall 16A as shown in FIG. 3. On the other hand, as shown in FIG. 4, since the vertical wall 16B is not abutted against the magnesium oxide layer 13, a space r1 exists therebetween. More specifically, the discharge spaces S of each of the display cells PC

adjacent to each other in the lateral direction of the two-dimensional display screen communicate with each other through the space **r1**.

Here, magnesium oxide crystals forming the magnesium oxide layer **13** contain monocrystals obtained by vapor phase oxidation of magnesium steam that is generated by heating magnesium, such as vapor phase magnesium oxide crystals that are excited by irradiating electron beams to do CL light emission having a peak within a wavelength range of 200 to 300 nm (particularly, near 235 nm within 230 to 250 nm). The vapor phase magnesium oxide crystals contain a magnesium monocrystal having a particle diameter of 2000 angstrom or greater with a polycrystal structure in which cubic crystals are fit into each other in a SEM photo image as shown in FIG. 5, or with a cubic monocrystal structure in a SEM photo image as shown in FIG. 6. The magnesium monocrystal has features of higher purity, finer particles and less particle coagulation than magnesium oxides generated by other methods, which contributes to improved discharge properties in discharge delay, etc. In addition, in the embodiment, the vapor phase magnesium oxide monocrystals, which are used, have an average particle diameter of 500 angstrom or greater measured by the BET method, preferably 2000 angstrom or greater. Then, as shown in FIG. 7, the magnesium oxide monocrystals are attached to the surface of the dielectric layer **12** by spraying or electrostatic coating to form the magnesium oxide layer **13**. Moreover, the magnesium oxide layer **13** may be formed in which a thin magnesium oxide layer is formed on the surface of the dielectric layer **12** and the increased dielectric layer **12A** by vapor deposition or sputtering and vapor phase magnesium oxide monocrystals are attached thereon.

The drive control circuit **56** supplies various control signals that drive the PDP **50** having the structure in accordance with the light emission addressing sequence adopting a subfield method (subframe method) as shown in FIG. 8 to the X-row electrode drive circuit **51**, the Y-row electrode drive circuit **53**, and the column electrode drive circuit **55**. The X-row electrode drive circuit **51**, the Y-row electrode drive circuit **53**, and the column electrode drive circuit **55** generate various drive pulses to be supplied to the PDP **50** in accordance with the light emission addressing sequence as shown in FIG. 8 and supply them to the PDP **50**.

In the light emission addressing sequence shown in FIG. 8, a display period for one field (one frame) has subfields SF1 to SF12, and the address stage W and the sustain stage I are implemented in each of the subfields SF1 to SF12. Furthermore, only in the starting subfield SF1, a reset stage R is implemented prior to the address stage W. The period of the sustain stage I for the subfields SF1 to SF12 is prolonged in order of SF1 to SF12. Moreover, the period where the address stage W is implemented is an address period, and the period where the sustain stage I is implemented is a sustain period.

FIG. 9 depicts a diagram illustrating all the patterns of light emission addressing implemented based on the light emission addressing sequence as shown in FIG. 8. 13 gray scales are formed by the light emission addressing sequence of the subfields SF1 to SF12. As shown in FIG. 9, in the address stage W in one subfield in the subfields SF1 to SF12, selective erasure discharge is implemented for each of the display cells for each of the gray scales (depicted by a black circle). More specifically, wall electric charge formed in all the display cells of the PDP **50** by implementing the reset stage R remains until selective erasure discharge is implemented, and prompts discharge and light emission in the sustain stage I in each subfield SF that is included during that remaining period (depicted by a white circle). Each of the display cells becomes a

light emission state while selective erasure discharge is being done for one field period, and 13 gray scales can be obtained by the length of the light emission state.

FIG. 10 depicts a diagram illustrating the application timing of various drive pulses to be applied to the column electrodes D, and the row electrodes X and Y of the PDP **50**, extracting SF1 and SF2 from the subfields SF1 to SF12.

In the reset stage R implemented prior to the address stage W only in the starting subfield SF1, the X-row electrode drive circuit **51** simultaneously applies a negative reset pulse RP_X to the row electrodes X_1 to X_n as shown in FIG. 10. The reset pulse RP_X has a pulse waveform that the voltage value is slowly increased to reach a peak voltage value over time. Furthermore, at the same time when the application of the reset pulse RP_X , the Y-row electrode drive circuit **53** simultaneously applies to the row electrodes Y_1 to Y_n a positive reset pulse RP_Y having a waveform that the voltage value is slowly increased to reach a peak voltage value over time as similar to the reset pulse RP_X as shown in FIG. 10. By the simultaneous application of the reset pulse RP_X and the reset pulse RP_Y , reset discharge is generated between the row electrodes X and Y in each of all the display cells $PC_{1,1}$ to $PC_{n,m}$. After the reset discharge is terminated, a predetermined amount of wall electric charge is formed on the surface of the magnesium oxide layer **13** in the discharge space S in each of the display cells PC. More specifically, it is the state that a so-called wall electric charge is formed in which positive electric charge is formed near the row electrode X and negative electric charge is formed near the row electrode Y on the surface of the magnesium oxide layer **13**.

In a panel on which the vapor phase magnesium oxide layer **13** is provided as a protective layer, since discharge probability is significantly high, weak reset discharge is stably generated. By combining a bump, particularly a T-shaped electrode in a broad tip end, reset discharge is localized near the discharge gap, and thus a possibility to generate sudden reset discharge such as discharge being generated in all the row electrodes is further suppressed. Therefore, discharge is hardly generated between the column electrode and the row electrode, and stable, weak reset discharge can be generated for a short time.

Furthermore, in the configuration that the vapor phase magnesium oxide layer **13** is provided, since the discharge probability is significantly improved, the application of a single reset pulse, that is, even a one-time reset discharge allows priming effect to be continued. Thus, the reset operation and the selective erasure operation can be further stabilized. Moreover, the number of times to do reset discharge is minimized to enhance contrast.

In addition, the effect of provision of the vapor phase magnesium oxide layer **13** will be described later.

Next, in the address stage W in each of the subfields SF1 to SF12, the Y-row electrode drive circuit **53** applies positive voltages to all the row electrodes Y_1 to Y_n , and sequentially applies a scanning pulse SP having a negative voltage to each of the row electrodes Y_1 to Y_n . While this is being done, the X-electrode drive circuit **51** changes the potentials of the electrodes X_1 to X_n to 0V. The column electrode drive circuit **55** converts each data bit in a pixel drive data bit group DB1 corresponding to the subfield SF1 to a pixel data pulse DP having a pulse voltage corresponding to its logic level. For example, the column electrode drive circuit **55** converts the pixel drive data bit of a logic level of 0 to the pixel data pulse DP of a positive high voltage, while converts the pixel drive data bit of a logic level of 1 to the pixel data pulse DP of a low voltage (0 volt). Then, it applies the pixel data pulse DP to the column electrodes D_1 to D_m for each display line in synchro-

nization with the application timing of a scanning pulse SP. More specifically, the column electrode drive circuit **55** first applies the pixel data pulse group DP1 formed of m pulses of the pixel data pulses DP corresponding to the first display line to the column electrodes D_1 to D_m , and then applies the pixel data pulse group DP2 formed of m pulses of the pixel data pulses DP corresponding to the second display line to the column electrodes D_1 to D_m . Between the column electrode D and the row electrode Y in the display cell PC to which the scanning pulse SP of the negative voltage and the pixel data pulse DP of the high voltage have been simultaneously applied, selective erasure discharge is generated to eliminate wall electric charge formed in the display cell PC. On the other hand, in the display cell PC to which the scanning pulse SP has been applied as well as the pixel data pulse DP of the low voltage (0 Volt), the selective erasure discharge as above is not generated. Therefore, the state to form wall electric charge is maintained in the display cell PC. More specifically, wall electric charge remains as it is when it exists in the display cell PC, whereas the state not to form wall electric charge is maintained when wall electric charge does not exist.

In this manner, in the address stage W based on the selective erasure addressing method, selective erasure addressing discharge is selectively generated in each of the display cells PC in accordance with each data bit in the pixel drive data bit group corresponding to the subfield, and then wall electric charge is removed. Thus, the display cell PC in which wall electric charge remains is set in the lighting state, and the display cell PC in which wall electric charge is removed is set in the unlighted state.

Subsequently, in the sustain stage I in each of the subfields, the X-row electrode drive circuit **51** and the Y-row electrode drive circuit **53** alternately, repeatedly apply positive sustain pulses IP_X and IP_Y to the row electrodes X_1 to X_n and Y_1 to Y_n . The number of times to apply the sustain pulses IP_X and IP_Y depends on weighting brightness in each of the subfields. At each time that the sustain pulses IP_X and IP_Y are applied, only the display cells PC in the lighting state do sustain discharge, the cells in which a predetermined amount of wall electric charge is formed, and the fluorescent material layer **17** emits light in association with this discharge to form an image on the panel surface.

As described above, the vapor phase magnesium monocrystals contained in the magnesium oxide layer **13** formed in each of the display cells PC are excited by irradiating electron beams to do CL light emission having a peak within a wavelength range of 200 to 300 nm (particularly, near 235 nm within 230 to 250 nm) as shown in FIG. **11**. As shown in FIG. **12**, the greater the particle diameter of each of the vapor phase magnesium oxide crystals is, the greater the peak intensity of CL light emission is. More specifically, when magnesium is heated at temperature higher than usual in generating the vapor phase magnesium oxide crystals, vapor phase magnesium oxide monocrystals having the average particle diameter of 500 angstrom are formed as well as relatively large monocrystals having the particle diameter of 2000 angstrom or greater as shown in FIG. **5** or FIG. **6**. Since temperature to heat magnesium is higher than usual, the length of flame generated by reacting magnesium with oxygen also becomes longer. Thus, the difference between a temperature of the flame and an ambient temperature becomes great, and therefore a group of vapor phase magnesium oxide monocrystals having a greater particle diameter particularly contain many monocrystals of high energy level corresponding to 200 to 300 nm (particularly near 235 nm).

FIG. **13** is a diagram illustrating discharge probabilities: the discharge probability when no magnesium oxide layer

was provided in the display cell PC; the discharge probability when the magnesium oxide layer is constructed by traditional vapor deposition; and the discharge probability when the magnesium oxide layer was provided which contained vapor phase magnesium oxide monocrystals to generate CL light emission having a peak at 200 to 300 nm (particularly near 235 nm within 230 to 250 nm) by irradiating electron beams. In addition, in FIG. **13**, the horizontal axis is dwell time of discharge, that is, a time interval from discharge being generated to next discharge being generated.

In this manner, when the magnesium oxide layer **13** is formed which contains the vapor phase magnesium oxide monocrystals that do CL light emission having a peak at 200 to 300 nm (particularly near 235 nm within 230 to 250 nm) by irradiating electron beams as shown in FIG. **5** or FIG. **6** in the discharge space S in each of the display cells PC, the discharge probability is higher than the case where the magnesium oxide layer is formed by traditional vapor deposition. In addition, as shown in FIG. **14**, for the vapor phase magnesium oxide monocrystals described above, those of greater CL light emission intensity having a peak particularly at 235 nm in irradiating electron beams can shorten discharge delay generated in the discharge space S.

Therefore, even though voltage transition of the reset pulse to be applied to the row electrode is made smooth to weaken reset discharge as shown in FIG. **10** in order to suppress light emission in association with reset discharge that relates to no display image and to improve contrast, this weak reset discharge can be stabilized for a short time to be generated. Particularly, since each of the display cells PC adopts the structure in which local discharge is generated near the discharge gap between the T-shaped transparent electrodes X_a and Y_a , a strong, sudden reset discharge that might be discharged in all the row electrodes can be suppressed as well as error discharge between the column electrode and the row electrode can be suppressed.

Furthermore, since the increased discharge probability (shortened discharge delay) allows a long, continuous priming effect by reset discharge in the reset stage R, address discharge generated in the address stage W and sustain discharge generated in the sustain stage I are high speed. Therefore, the pulse widths of the pixel data pulse DP and the scanning pulse SP to be applied to the column electrode D and the row electrode Y in order to generate address discharge as shown in FIG. **10** can be shortened. By that amount, processing time for the address stage W can be shortened. Moreover, the pulse width of the sustain pulse IP_Y to be applied to the row electrode Y in order to generate sustain discharge as shown in FIG. **10** can be shortened. By that amount, processing time for the sustain stage I can be shortened.

Accordingly, by the amount of the shortened processing time for each of the address stage W and the sustain stage I, the number of subfields to be provided in one field (or one frame) display period can be increased, and the number of gray scales can be intended to increase.

FIG. **15** depicts a specific configuration of the X-row electrode drive circuit **51** and the Y-row electrode drive circuit **53** on electrodes X_j and Y_j . The electrode X_j is the electrode at the j th line in electrodes X_1 to X_n , and the electrode Y_j is the electrode at the j th line in the electrodes Y_1 to Y_n . The portion between the electrodes X_j and Y_j serves as a capacitor CO.

In the X-row drive circuit **51**, two power sources B1 and B2 are provided. The power source B1 outputs a voltage V_s (for example, 170 V), and the power source B2 outputs a voltage V_r (for example, 190 V). A positive terminal of the power source B1 is connected to a connection line **21** for the electrode X_j through a switching element S3, and a negative

terminal thereof is grounded. Between the connection line **21** and the ground, a switching element **S4** is connected, as well as a series circuit formed of a switching element **S1**, a diode **D1** and a coil **L1**, and a series circuit formed of a coil **L2**, a diode **D2** and a switching element **S2** are connected to the ground side commonly through a capacitor **C1**. In addition, the diode **D1** has an anode on the capacitor **C1** side, and the diode **D2** is connected as the capacitor **C1** side is a cathode. Furthermore, a negative terminal of the power source **B2** is connected to the connection line **21** through a switching element **S8** and a resistor **R1**, and a positive terminal of the power source **B2** is grounded.

In the Y-row electrode drive circuit **53**, four power sources **B3** to **B6** are provided. The power source **B3** outputs a voltage V_s (for example, 170 V), the power source **B4** outputs a voltage V_r (for example, 190 V), the power source **B5** outputs a voltage V_{off} (for example, 140 V), and the power source **B6** outputs a voltage v_n (for example, 160 V, $V_n > V_{off}$). A positive terminal of the power source **B3** is connected to a connection line **22** for a switching element **S15** through a switching element **S13**, and a negative terminal thereof is grounded. Between the connection line **22** and the ground, a switching element **S14** is connected as well as a series circuit formed of a switching element **S11**, a diode **D3** and a coil **L3**, and a series circuit formed of a coil **L4**, a diode **D4** and a switching element **S12** are connected to the ground side commonly through a capacitor **C2**. In addition, the diode **D3** has an anode on the capacitor **C2** side, and the diode **D4** is connected as the capacitor **C2** side is a cathode.

The connection line **22** is connected to a connection line **23** for a negative terminal of the power source **B6** through the switching element **S15**. A negative terminal of the power source **B4** and a positive terminal of the power source **B5** are grounded. A positive terminal of the power source **B4** is connected to the connection line **23** through a switching element **S16** and a resistor **R2**, and a negative terminal of the power source **B5** is connected to the connection line **23** through a switching element **S17**.

A positive terminal of the power source **B6** is connected to a connection line **24** for the electrode Y_j through a switching element **S21**, and the negative terminal of the power source **B6** connected to the connection line **23** is connected to the connection line **24** through a switching element **S22**. The diode **D5** is connected in parallel to the switching element **S21**, and the diode **D6** is connected in parallel to the switching element **S22**. The diode **D5** has an anode on the connection line **24** side, and the diode **D6** is connected as the connection line **24** side is a cathode.

The drive control circuit **56** controls turning on and off the switching elements **S1** to **S4**, **S8**, **S11** to **S17**, **S21** and **S22**.

In the X-row electrode drive circuit **51**, the resistor **R1**, the switching elements **S8** and the power source **B2** configure a resetting portion, and the remaining elements configure a sustaining portion. In addition, in the Y-row electrode drive circuit **53**, the power source **B3**, the switching elements **S11** to **S15**, the coils **L3** and **L4**, the diodes **D3** and **D4**, and the capacitor **C2** configure a sustaining portion, the power source **B4**, the resistor **R2**, and the switching element **S16** configure a resetting portion, and the remaining power sources **B5** and **B6**, the switching elements **S13**, **S17**, **S21**, **S22**, and the diodes **D5** and **D6** configure an addressing portion and a discharge timing controller.

Next, the operations of the X-row electrode drive circuit **51** and the Y-row electrode drive circuit **53** in this configuration will be described with reference to a time chart shown in FIG. 16.

First, in the reset stage, the switching element **S8** of the X-row electrode drive circuit **51** is turned on, and the switching elements **S16** and **S22** of the Y-row electrode drive circuit **53** are both turned on. The other switching elements are off. Turning on the switching elements **S16** and **S22** carries current from the positive terminal of the power source **B4** to the electrode Y_j through the switching element **S16**, the resistor **R2** and the switching element **S22**, and turning on the switching element **S8** carries current from the electrode X_j through the resistor **R1**, and the switching element **S8** to the negative terminal of the power source **B2**. The potential of the electrode X_j is gradually decreased by the time constant of the capacitor **CO** and the resistor **R1**, and is the reset pulse PR_X , whereas the potential of the electrode Y_j is gradually increased by the time constant of the capacitor **CO** and the resistor **R2**, and is the reset pulse PR_Y . The reset pulse PR_X finally becomes a voltage $-V_r$, and the reset pulse PR_Y finally becomes a voltage V_r . The reset pulse PR_X is applied to all the electrodes X_1 to X_n at the same time, and the reset pulse PR_Y is generated for each of the electrodes Y_1 to Y_n and is applied to all the electrodes Y_1 to Y_n .

The simultaneous application of the reset pulses RP_X and RP_Y , all the display cells of the PDP **1** are discharge excited to generate charged particles, and after terminating the discharge, a predetermined amount of wall electric charge is evenly formed on the dielectric layer of all the display cells.

After the levels of the reset pulses RP_X and RP_Y are saturated, the switching elements **S8** and **S16** are turned off before the reset stage is ended. Furthermore, the switching elements **S4**, **S14** and **S15** are turned on at this time, and the electrodes X_j and Y_j are both grounded. Thus, the reset pulses RP_X and RP_Y disappear.

Subsequently, when the address stage is started, the switching elements **S14**, **S15** and **S22** are turned off, the switching element **S17** is turned on, and the switching element **S21** is turned on at the same time. Thus, since the power source **B6** is serially connected to the power source **B5**, the potential of the positive terminal of the power source **B6** is $V_n - V_{off}$. The positive potential is applied to the electrode Y_j through the switching element **S21**.

In the address stage, the column electrode drive circuit **55** converts pixel data for each pixel based on the video signal to the pixel data pulses DP_1 to DP_n having a voltage value corresponding to its logic level, and sequentially applies them to the column electrodes D_1 to D_m for each one display line. As shown in FIG. 16, the pixel data pulses DP_j , DP_{j+1} with respect to the electrodes Y_j , Y_{j+1} are applied to the column electrode D_i .

The Y-row electrode drive circuit **53** sequentially applies the scanning pulse **SP** of the negative voltage to the row electrodes Y_1 to Y_n in synchronization with the timing of each of the pixel data pulse groups DP_1 to DP_n .

In synchronization with the application of the pixel data pulse DP_j from the column electrode drive circuit **55**, the switching element **S21** is turned off, and the switching element **S22** is turned on. Thus, the negative potential $-V_{off}$ of the negative terminal of the power source **B5** is applied to the electrode Y_j as the scanning pulse **SP** through the switching element **S17** and the switching element **S22**. Then, in synchronization with the stop of the application of the pixel data pulse DP_j from the column electrode drive circuit **55**, the switching element **S21** is turned on, the switching element **S22** is turned off, and the potential $V_n - V_{off}$ of the positive terminal of the power source **B6** is applied to the electrode Y_j through the switching element **S21**. After that, as shown in FIG. 16, the scanning pulse **SP** is applied to the electrode Y_{j+1} .

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as similar to the electrode Y_j in synchronization with the application of the pixel data pulse DP_{j+1} from the column electrode drive circuit **55**.

In the display cells belonging to the row electrode to which the scanning pulse SP has been applied, discharge is generated in the display cell to which the pixel data pulse of the positive voltage has been further applied at the same time, and most of its wall electric charge are lost. On the other hand, since discharge is not generated in the display cell to which the scanning pulse SP has been applied but the pixel data pulse of the positive voltage has not been applied, the wall electric charge still remains. The display cell in which the wall electric charge remains is in the lighting state, and the display cell in which the wall electric charge has disappeared is in the unlighted state.

When the address stage is ended, the sustain stage is started. In the sustain stage, the switching elements **S17** and **S21** are turned off, and the switching elements **S14**, **S15** and **S22** are instead turned on. The ON-state of the switching element **S4** continues.

In the sustain stage, the X-row electrode drive circuit **51** allows the switching element **S4** to continue to be in the ON state, so that the electrode X_j is at the ground potential (the first potential) of approximately 0V. The Y-row electrode drive circuit **53** allows the switching element **S14** to be turned on, such that the electrode Y_j is at the ground potential of approximately 0V.

Thereafter, the switching elements **S14**, **S15**, and **S22** are turned off, and at the same time, the switching elements **S17** and **S21** are turned on. This causes the power supply **B6** and the power supply **B5** to be connected in series to each other, so that the positive terminal of the power supply **B6** is at the potential of $V_n - V_{off}$. This positive potential is applied to the electrode Y_j via the switching element **S21**, as a discharge timing control pulse TP.

The pulse width of the discharge timing control pulse TP may differ according to a display cell or a plurality of display cells. However, discharge timing control pulses TP having different pulse widths may be applied to the respective row electrodes Y_1 to Y_n (display lines), or alternatively to the respective groups of display lines into which all the display lines have been divided.

During the application of the discharge timing control pulse TP in the X-row electrode drive circuit **51**, when the switching element **S4** is turned off and the switching element **S1** is turned on, current reaches the electrode X_j through the coil **L1**, the diode **D1**, and the switching element **S1** by electric charge charged in the capacitor **C1** to flow into the capacitor **CO**, and then the capacitor **CO** is charged. At this time, the time constant of the coil **L1** and the capacitor **CO** gradually increases the potential of the electrode X_j as shown in FIG. **16**. The potential increase is the leading of a sustain pulse IP_X .

Then, the switching element **S3** is turned on. Thus, the potential V_s (second potential) of the positive terminal of the power source **B1** is applied to the electrode X_j , and the potential of the electrode X_j is clamped to V_s .

After the electrode X_j has been clamped to the potential V_s , the Y-row electrode drive circuit **53** allows the switching elements **S17** and **S21** to be turned off, and the switching elements **S14**, **S15**, and **S22** to be turned on instead. The electrode Y_j is now at the ground potential of approximately 0V, and the discharge timing control pulse TP disappears.

After the discharge timing control pulse TP has disappeared, the switching elements **S1** and **S3** are turned off, the

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switching element **S2** is turned on, and current is carried from the electrode X_j into the capacitor **C1** through the coil **L2**, the diode **D2**, and the switching element **S2** by the electric charge charged in the capacitor **CO**. At this time, the time constant of the coil **L2** and the capacitor **C1** gradually decreases the potential of the electrode X_j as shown in FIG. **16**. The potential decrease is the trailing of the sustain pulse IP_X . When the potential of the electrode X_j reaches nearly 0V, the switching element **S2** is turned off, and the switching element **S4** is turned on.

By this operation, the X-row electrode drive circuit **51** applies the sustain pulse IP_X of the positive voltage to the electrode X_j as shown in FIG. **16**.

In the Y-row electrode drive circuit **53**, at the same time when turning on the switching element **S4** where the sustain pulse IP_X disappears, the switching element **S11** is turned on, and the switching element **S14** is turned off. The potential of the electrode Y_j is the ground potential of nearly 0V when the switching element **S14** is on. However, when the switching element **S14** is turned off and the switching element **S11** is turned on, current reaches the electrode Y_j through the coil **L3**, the diode **D3**, the switching element **S11**, the switching element **S15**, and the diode **D6** by electric charge charged in the capacitor **C2** to flow into the capacitor **CO**, and then the capacitor **CO** is charged. At this time, the time constant of the coil **L3** and the capacitor **CO** gradually increases the potential of the electrode Y_j as shown in FIG. **16**. The potential increase is the leading of a sustain pulse IP_Y .

Subsequently, the switching element **S13** is turned on. Thus, the potential V_s of the positive terminal of the power source **B3** is applied to the electrode Y_j through the switching element **S13**, the switching element **S15**, and the diode **D6**.

After that, the switching elements **S11** and **S13** are turned off, the switching element **S12** is turned on, the switching element **S22** is turned on, and current flows from the electrode Y_j into the capacitor **C2** through the switching element **S22**, the switching element **S15**, the coil **L4**, the diode **D4**, and the switching element **S12** by electric charge charged in the capacitor **CO**. At this time, the time constant of the coil **L4** and the capacitor **C2** gradually decreases the potential of the electrode Y_j as shown in FIG. **16**. The potential decrease is the trailing of the sustain pulse IP_Y . When the potential of the electrode Y_j reaches nearly 0V, the switching elements **S12** and **S22** are turned off, and the switching element **S14** is turned on.

By this operation, the Y-row electrode drive circuit **53** applies the sustain pulse IP_Y of the positive voltage to the electrode Y_j as shown in FIG. **16**.

In this manner, in the sustain stage, since the sustain pulse IP_X and the sustain pulse IP_Y are alternately generated and alternately applied to the electrodes X_1 to X_n and the electrodes Y_1 to Y_n , the display cell in which the wall electric charge still remains repeats discharge light emission to maintain its lighting state.

FIG. **17** shows discharge intensities that are provided at a cell where a discharge occurs earlier and at a cell where a discharge occurs later, when the first sustain pulse IP_X is applied thereto in the sustain stage without the application of the discharge timing control pulse TP. In this case, when multiple display cells are in a lighting state, discharge currents intensively flow to distort the waveform of the first sustain pulse IP_X . This causes the discharge timings of the display cells to be different from each other and results in a reduced discharge intensity being provided at a cell where the discharge occurs later when compared to a cell where the

discharge occurs earlier. The difference in the discharge intensity thus increased leads to variations in brightness. On the other hand, FIG. 18 shows discharge intensities that are provided at respective display cells on the electrodes Y_j and Y_{j+1} when the first sustain pulse IP_X is applied thereto in the sustain stage with the application of the discharge timing control pulse TP. In this case, the pulse width of the discharge timing control pulse TP applied to the electrode Y_j is different from the pulse width of the discharge timing control pulse TP applied to the electrode Y_{j+1} . The application of the discharge timing control pulses TP starts at the same time, but the discharge timing control pulse TP applied to the electrode Y_{j+1} is greater in pulse width. While the discharge timing control pulse TP exists, no sustain discharge occurs even in the presence of the first sustain pulse IP_X . The discharge timing control pulse TP can be provided with a different pulse width for each display row (line) in this manner, thereby allowing the discharge timing to be shifted for each display row at the time of application of the first sustain pulse IP_X . That is, since intensive discharge timing can be prevented at all the display cells that are in a lighting state, the discharge currents can not flow in time and the waveform of the first sustain pulse IP_X can be prevented from distorting. Accordingly, it is possible to provide generally the same discharge intensity at each display cell, thereby improving variations in brightness.

In the aforementioned embodiment, although the plasma display panel using specific vapor phase magnesium is applied to the display device, the present invention is not limited thereto. The invention is also applicable to a plasma display panel with reduced discharge delay and reduced discharge variations, also providing the same effects.

In addition, for the PDP 50 in the embodiment, the structure is adopted in which the display cell PC is formed between the row electrodes X and the row electrodes Y that are paired with each other as (X_1, Y_1) , (X_2, Y_2) , (X_3, Y_3) , . . . , (X_n, Y_n) . However, the structure may be adopted in which the display cell PC is formed between all the row electrodes. More specifically, the structure may be adopted in which the display cell PC is formed between the row electrodes X_1 and Y_1 , the row electrode Y_1 and X_2 , the row electrode X_2 and Y_2 , . . . , the row electrode Y_{n-1} and X_n , the row electrode X_n and Y_n .

Furthermore, for the PDP 50 in the embodiment, the structure is adopted in which the row electrodes X and Y are formed in the front transparent substrate 10 and the column electrode D and the fluorescent material layer 17 are formed in the rear substrate 14. However, the structure may be adopted in which the column electrodes D as well as the row electrodes X and Y are formed in the front transparent substrate 10 and the fluorescent material layer 17 is formed in the rear substrate 14.

As described above, according to the present invention, in the sustain period, the discharge timing control pulse of the same polarity as that of a sustain pulse, which is first applied to one row electrode of a row electrode pair, is applied to the other row electrode of the row electrode pair to overlap each other in terms of time. In the sustain period, it is possible to prevent variation in discharge intensity at each display cell even when multiple display cells are set in a lighting state, thereby providing improved display quality.

This application is based on Japanese Patent Application No. 2005-182422 which is hereby incorporated by reference.

What is claimed is:

1. A plasma display device having a plasma display panel, for displaying an image on said plasma display panel in accordance with an input video signal, said plasma display panel having a plurality of row electrode pairs, and a plurality of column electrodes intersecting with said plurality of row electrode pairs, so as to form display cells at the intersections, respectively, and a display period for one field of the input video signal being configured of a plurality of subfields each formed of an address period and a sustain period for the image display,

wherein said plasma display panel includes: a front transparent substrate on which a dielectric layer is formed to cover said plurality of row electrode pairs; a rear substrate, disposed in parallel with said front transparent substrate, on which a protective layer is formed to cover said plurality of column electrodes; a fluorescent material layer formed on said protective layer to face a discharge space for each of said display cells; and a magnesium oxide layer formed on said dielectric layer to face the discharge space, containing magnesium oxide monocrystals which are excited by irradiating an electron beam in each of said display cells to emit cathode luminescence light having a peak within a wavelength range of 200 to 300 nm,

said plasma display device comprising:

an addressing portion which selectively generates address discharge in each of said display cells in accordance with pixel data based on the video signal in the address period;

a sustaining portion which applies a sustain pulse between row electrodes forming each of said row electrode pairs in said sustain period; and

a discharge timing controller which applies, in the sustain period, a discharge timing control pulse of a same polarity as that of the sustain pulse, to one row electrodes of the row electrode pairs, so that the discharge timing control pulse partly overlaps with a first sustain pulse in terms of time, which is applied to the other row electrodes of the row electrode pairs by said sustaining portion.

2. The plasma display device according to claim 1, wherein said discharge timing controller applies the discharge timing control pulse having a different period of overlap with the applied first sustain pulse, to the one row electrodes for each display line or a group of display lines.

3. The plasma display device according to claim 1, wherein each row electrode forming the row electrode pairs includes a main portion extending in a row direction, and a projected portion projected from the main portion in a column direction so as to oppose each other via a discharge gap.

4. The plasma display device according to claim 1, wherein said magnesium oxide layer contains the magnesium oxide monocrystals having a particle diameter of 2000 angstrom or greater.

5. The plasma display device according to claim 1, wherein said magnesium oxide crystals emit cathode luminescence light having a peak within a wavelength range of 230 to 250 nm.